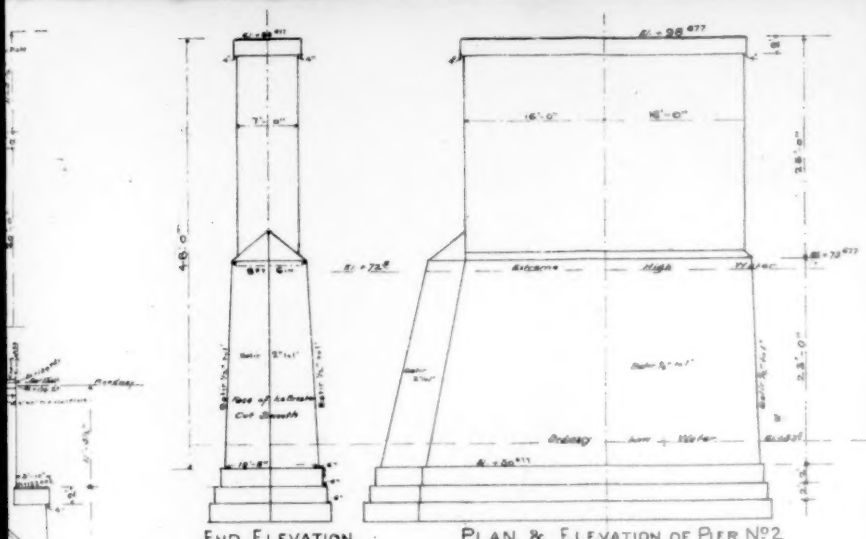
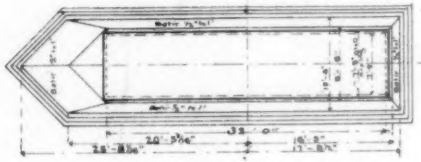
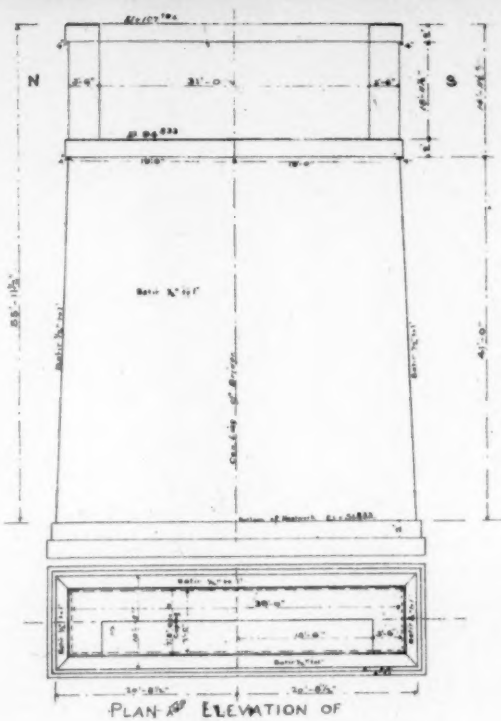


END ELEVATION
PIER Nº2.

PLAN & ELEVATION OF PIER Nº2





PLAN & ELEVATION OF
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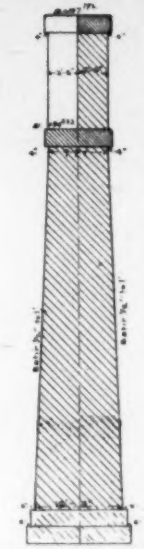
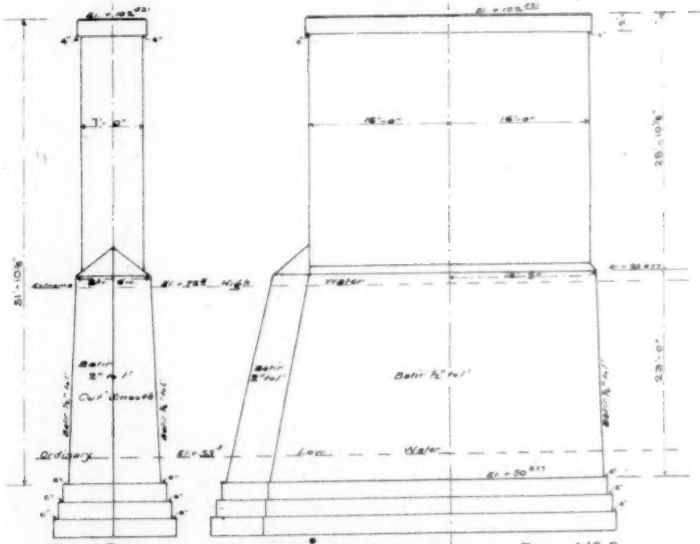


SEC ON CEN LINE
OF BRIDGE
PIER NUMBER 1



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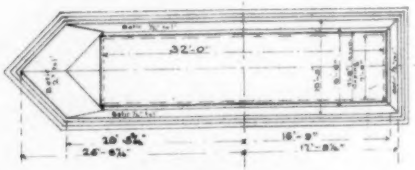

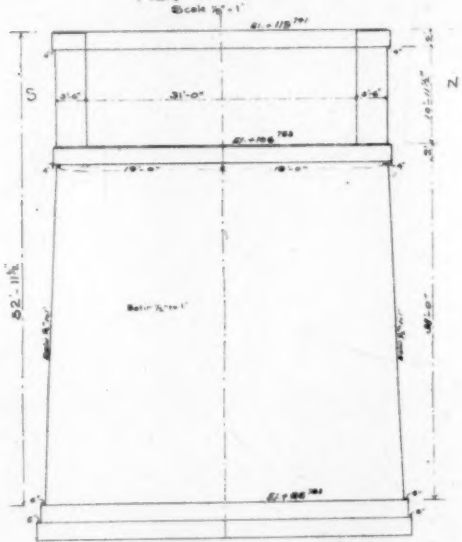

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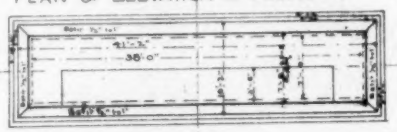

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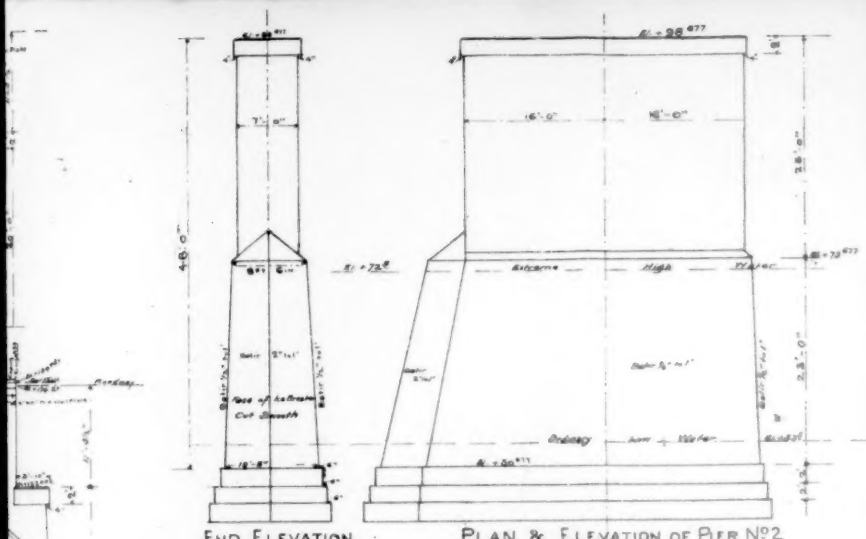

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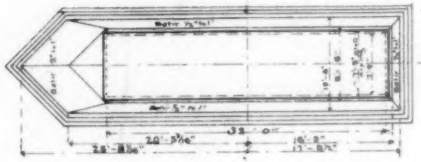
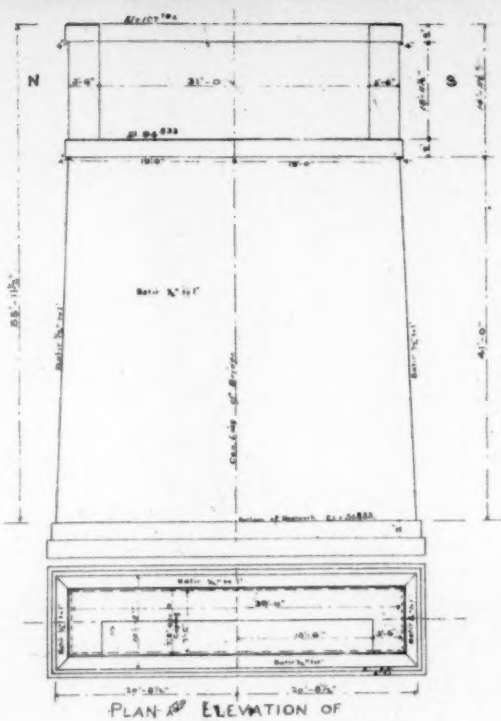
PLAN & ELEVATION OF PIER Nº2





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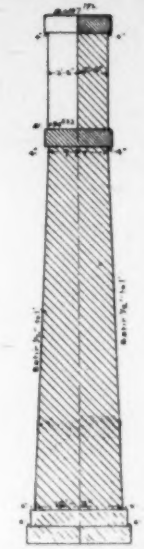

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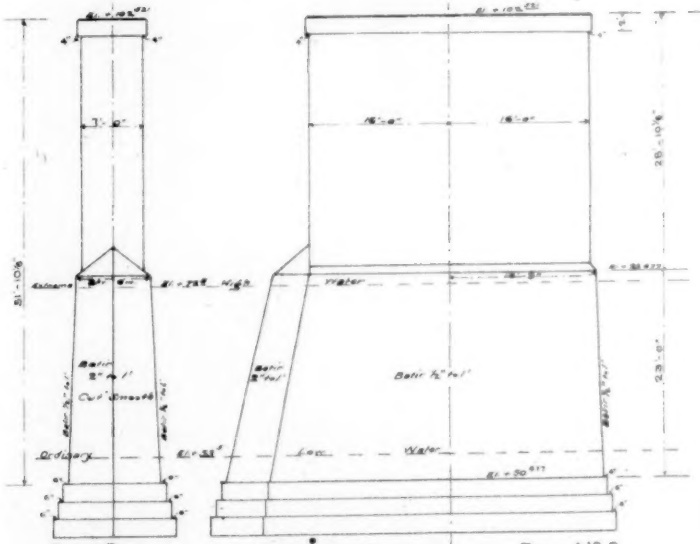
PIER NUMBER 1



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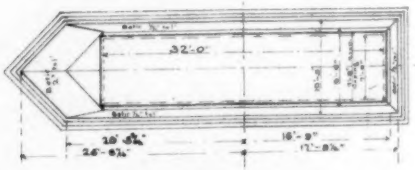
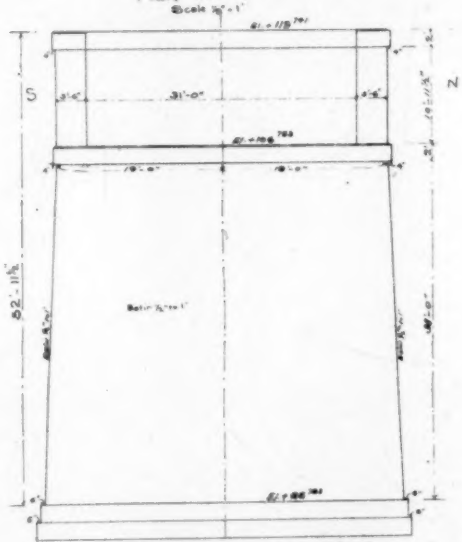
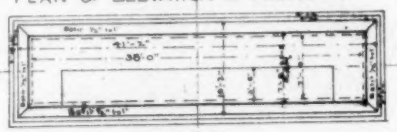
PLAN & ELEVATION OF PIER Nº3.





PLAN & ELEVATION OF PIER Nº 4



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JOURNAL

OF THE

FRANKLIN INSTITUTE

OF THE STATE OF PENNSYLVANIA,

FOR THE PROMOTION OF THE MECHANIC ARTS.

VOL. CXXXIX. APRIL, 1895. No. 4

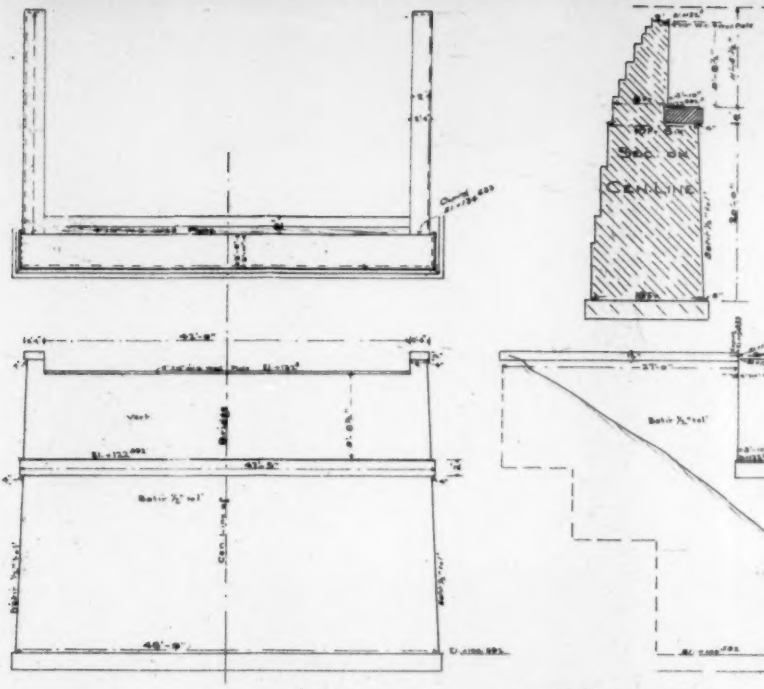
THE Franklin Institute is not responsible for the statements and opinions advanced by contributors to the *Journal.*

THE CITY AVENUE BRIDGE OVER THE SCHUYLKILL RIVER, PHILADELPHIA.

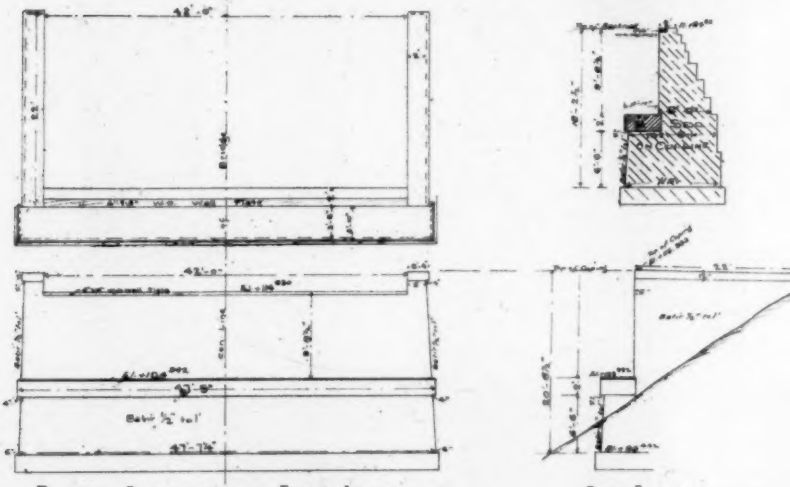
BY J. VAUGHAN MERRICK.

This bridge, having passed into the hands of the city, and the corporation which built it having been dissolved, it seems proper that so important a municipal improvement should have its history recorded.

For many years past, efforts have been made by those especially interested, to have the Schuylkill bridged at a point near the mouth of the Wissahickon; and old maps of that region show the projected lines for such a bridge, extending from Ridge Avenue immediately south of Wissahickon Creek, upon the eastern side, crossing to a point in line with City Avenue on the western side; which avenue, beginning at a point a few hundred feet from the river, forms the boundary between Philadelphia and Montgomery counties.



PLAN & ELEVATIONS WEST ABUTMENT



PLAN & ELEVATION OF EAST ABUT.

SIDE ELEV.

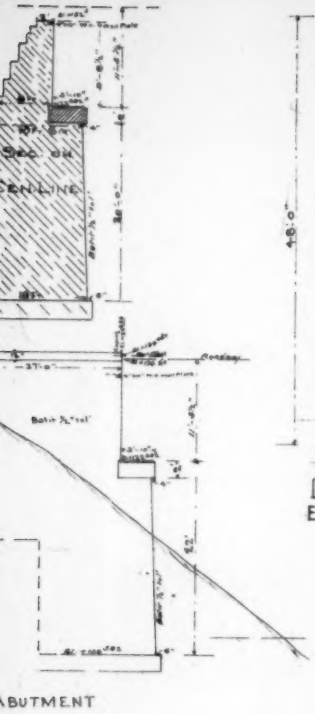
CITY AVENUE BR

MASONRY PLAN

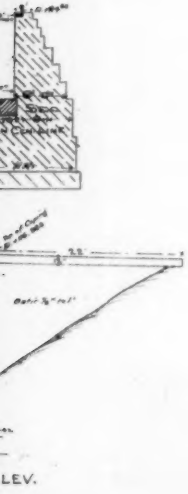
DETAILS OF PIERS AND ABU

SCALE ⅜" = 1ft.

Phila, Pa. Apr. 6th 1889.



ABUTMENT



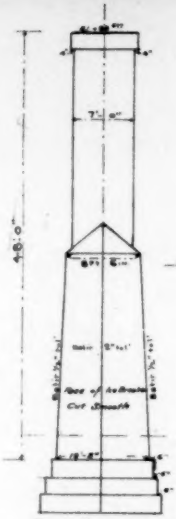
LEV.

NUE BRIDGE

PLAN

AND ABUTMENTS.

LE 1/8" = 1 FT.



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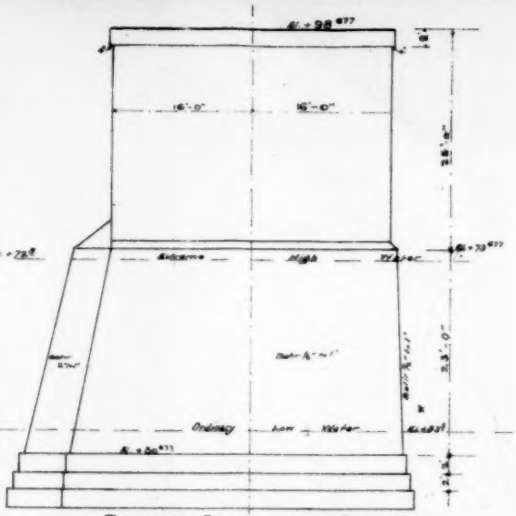
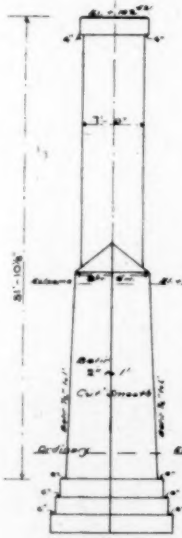


PLAN & ELEVATION OF PIER Nº2.



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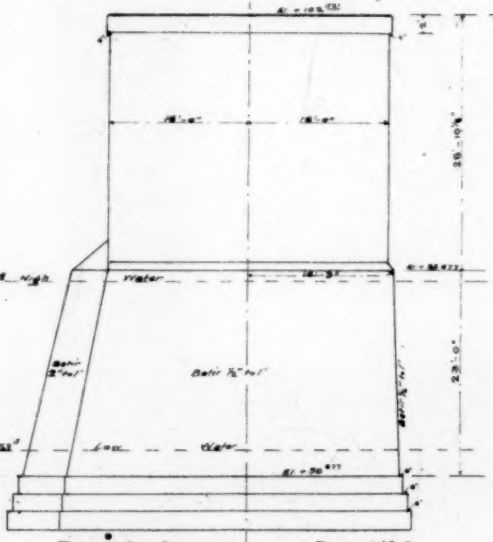

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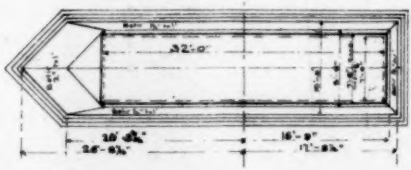


Until the completion of City Avenue bridge, no means of communication existed between the two sides of the Schuylkill, from the Manayunk "toll bridge," at the northern end of that suburb, to the "Falls bridge," a distance of about two miles. To both these bridges the approaches from the high table lands on the western side are by hilly and poorly-made country roads. The lower one passes under a low arch on the Reading Railroad, and is dangerous, besides being almost impracticable in winter on account of the grade. The growth of the city in its western wards, in Roxborough and Germantown, called for better facilities of communication between them, and the project of erecting a bridge on the lines above indicated assumed increased importance. As there seemed no probability of getting the city to undertake it, a number of gentlemen, supposed to be interested in promoting its construction, met at the house of Mr. Justus C. Strawbridge, on School Lane, in the latter part of 1887. At this meeting the necessity of better communication was presented and plans were discussed. Two views were advocated, one of which was to connect School Lane by an elevated structure across the Reading (Norristown branch) Railroad and Park Meadow, to the knoll south of the Wissahickon, thence to bridge the Schuylkill; the other for the latter part of this scheme only. For many reasons, on which I need not enlarge, the latter view prevailed, as affording immediate relief at a much lower cost, and also as extending the drives of the park, connecting them with the fine system of turnpike roads in Montgomery County adjoining City Line, and also with West Philadelphia.

A company, under the name of "Germantown and City Avenue Bridge Company," was chartered March 8, 1888, and the first meeting of the Board of Directors was held March 26, 1888. This board consisted of Justus C. Strawbridge, *President*, and J. Vaughan Merrick, George B. Roberts, William P. Henszey, David Scull, Reed A. Williams, Jr., and J. C. Harris, with E. W. Clark, *Secretary and Treasurer*. Subscriptions to the capital stock, amounting to $110,000, were secured. An ordinance was passed by the City Councils and approved by the Mayor (Hon. E. H. Fitler) in June, 1888,

authorizing the erection and location of the bridge, ceding the necessary ground for approach and right of way, upon the approval of the plans by the Department of Public Works, the Survey Department and the Commissioners of Fairmount Park. By this ordinance the city reserved the right to purchase the bridge at cost, upon a sworn statement thereof at completion, or to lease it at five per cent. thereupon, and also to pay the State tax and maintain it in good repair. The Mayor was to exercise this option within two years of the completion.

After careful surveys had been made as to the location of approaches and river soundings, several plans were successively prepared and considered, questions of cost entering largely into their consideration. Finally, the company determined upon a five-span bridge with plank floor, and adopted a plan prepared by W. H. Brown, Esq., assisted by Mr. H. A. Pratt. This plan was approved by the authorities above named, and is the one on which the bridge was built. The total length is 706 feet, viz.: two end spans of 114 feet; three channel spans of 170 feet 6 inches (west), 153 feet 9 inches, and 153 feet 9 inches respectively. Width of roadway, 30 feet, and two sidewalks, 6 feet each; a total width of 42 feet; Pratt truss for channel spans; roadway on upper chord; piers of cut stone from Conshohocken quarry; superstructure of iron; road and footways of plank (two thicknesses), and an ornamental iron railing and lamp-posts on each side. The strength of the superstructure is equal to that usually required for railroad bridges, and, therefore, far in excess of the proportions commonly adopted for highway bridges. In all the details of design and construction, consultation was had with the (then) head of the Survey Department of the City of Philadelphia, the late Samuel L. Smedley, and his approval obtained. The bridge is of considerable height, and its roadway is inclined 12 feet, being 77¾ feet above mean low water at the western end, and 65¾ feet at the eastern end.

The data for calculations were as follows:

Assumed loading, 80 pounds per square foot of roadway and sidewalks, in addition to weight of structure.

Wind stresses, on upper lateral bracing, 200 pounds per lineal foot, static load; 100 pounds per foot, moving load.

Working stresses, tension, eye bars, 12,000 pounds per square inch.

Working stresses, tension, plate and shape iron, 10,000 pounds per square inch.

Working stresses, tension, counter rods, 9,000 pounds per square inch.

Working stresses, tension, lateral and sway rods, 15,000 pounds per square inch.

Working stresses, compression, built members (taking compression only), 8,000 pounds per square inch.

Working stresses, compression, web members in three middle panels of end spans, 5,000 pounds per square inch.

Maximum fibre stress in pins, 15,000 pounds per square inch.

The company contracted for the stone-work, after public advertisement, and awarded the same to the lowest bidder, John B. Reilly & Co.

The iron work was submitted to eight first-class railway bridge builders, and the contract was awarded to Cofrode & Saylor, the lowest bidders conforming to the specifications. The board appointed as a building committee, Messrs. Merrick, Roberts and Henszey; and elected Frederick J. Amweg, C.E., as the constructing engineer. Under his charge the work was completed, and the two approaches in Fairmount Park graded, macadamized and planted. The total cost of the entire work, including expenses of organization and interest upon advance payments up to completion, was $109,807.42.

Work was begun in April, 1889, and was to have been completed in five months; but owing to delay in beginning the stone-work, and excessive and repeated floods during the summer, which carried away the coffer dams, it was not opened for travel until May 30, 1890, and was finally completed October 1, 1890, when a statement of cost, as above, was filed with the city.

The traffic upon the bridge immediately showed the wisdom of its projectors, and justified their belief that it was

greatly needed. It earned from the beginning four per cent. on its cost after paying all expenses; and travel gradually increased, until five per cent. was earned at the time (1893) the Falls bridge was carried away by freshets. After that date, of course, the increase was more rapid, as all adjacent travel was thrown upon it.

In their dealings with the company, the city authorities have not appeared to recognize the public spirit of the projectors of the enterprise, or the benefits it would secure, in the development of suburban territory and the convenience of the traveling public.

The ordinance granting permission for its erection prescribed, as has been stated, certain terms upon which it might be bought or leased, which terms simply secured the subscribers against loss. When, however, the Mayor elected to lease it, Councils offered inferior terms to those prescribed by their own ordinance, and less than the bridge was already earning. The offer was, of course, declined.

Some months later, December 28, 1892, certain citizens on the west side and others, unconnected with the company, began proceedings before the Court of Quarter Sessions to compel the city to free the bridge from tolls, under the State Act of May 8, 1876, providing for such cases.

The Court (BIDDLE, J.) decided, December 5, 1893, that these proceedings should be set aside, on the ground that, although the act provided for taking bridges in any county in the State, yet that Philadelphia County having been erected into a municipality, the act thereby ceased to be operative therein. The case was carried to the Supreme Court of Pennsylvania, when the action of the lower court was reversed on the ground that Philadelphia was still a county, and its citizens could not be deprived of the only means for freeing bridges which had been provided by the Legislature. New proceedings were ordered October 22, 1894. The case was accordingly brought before the Grand Jury by Judge Reed, when, on November 2, 1894, the bridge was ordered to be taken for public use at a valuation equal to its cost. Possession was given on November 20th, the city retaining the tolls collected to that date from the 2d inst.

The accompanying illustrations show a structure which will compare favorably, either in appearance or strength, with any bridge erected by the municipality. As to cost, it is, of course, impracticable to make a fair comparison, owing to the diverse conditions existing in different bridges. But it is certain that the expense incurred in its construction is far less than would have been possible under city contracts. It was built by business men, who gave their services without compensation, and upon methods calculated to ensure a minimum cost with the most direct responsibility. Separate contracts with principals, for stone-work and superstructure, instead of one contract for the whole work, enabled the company to obtain the most economical results from the best bidders.

THE REDHEFFER PERPETUAL MOTION MACHINE.

BY HENRY MORTON.

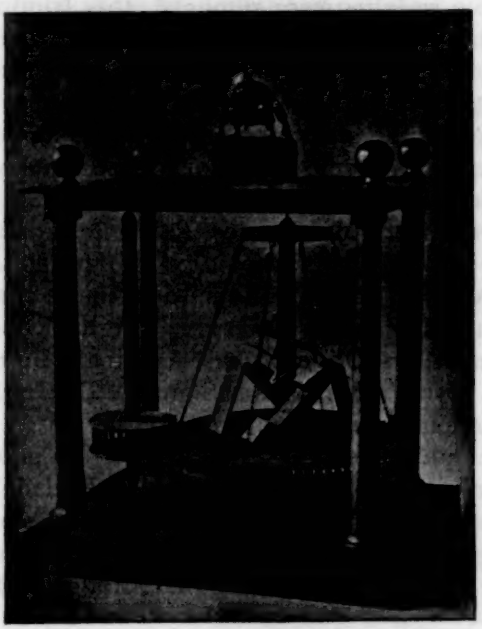
In the museum of the Franklin Institute, at Philadelphia, is a curious model, which was made about eighty years ago, by Isaiah Lukens, for the purpose of exposing the fraud involved in the (then) famous Redheffer Perpetual Motion Machine, in which large sums of money were sunk, as they have been more recently in the "Keely Motor" and like schemes.

This model, represented in the accompanying engraving, consists of a horizontal circular table, attached to, and supported by, a central vertical shaft, resting on a pivot below and steadied by a journal held in a framework above. Two inclined planes, mounted on wheels, rest on this circular table, and each inclined plane has on it a car containing two removable weights.

The inclined planes, and also the cars, are attached to levers which are supposed to transmit to the central shaft the tendencies of the inclined planes to run from under the cars, and of the cars to run down the inclined planes, and

these tendencies are supposed to cause rotation of the central shaft, carrying with it the table and all the parts on it.

A model identical in appearance with this was for many years exhibited in the Philadelphia Museum, but was destroyed when that museum was burned down. In that model, if the weights were taken out of the cars, the machine would come to rest, but would start up again as soon



Isaiah Lukens' model of the "Redheffer Perpetual Motion," in the collection of the Franklin Institute.

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Here is a phenomenon which might well startle a novice, but he would do well to hold fast to his faith in the conservation of energy, and to insist on a further investigation into the interior of the apparatus; for this is what such an investigation would reveal:

A train of clock-work, driven by a spring, was concealed

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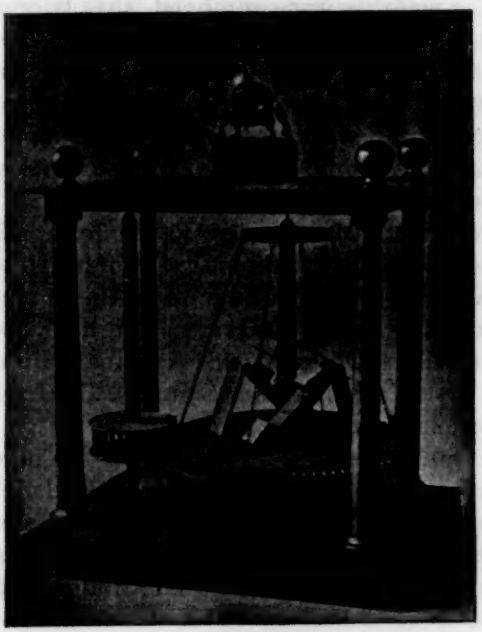

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A train of clock-work, driven by a spring, was concealed

in the base of the machine, and could be wound up by a slight movement of one of the ornaments on the frame of a glass case, which covered and *locked up* the model beyond seeming possibility of tampering. This clock-work drove a small plate, on which rested the pivot of the central vertical shaft; and the various frictions were so adjusted, that when the cars were loaded, the weight thus added would increase the friction of the little plate sufficiently to drive the shaft; but when the weights were removed, this friction was too slight. An attendant, touching the outside case for a moment, once a day, under pretence of dusting or the like, could keep the spring wound up perpetually.

Such, then, is the structure, and such the mode of operation, of this very ingenious model, whose history, which is also extremely interesting, I will now give.

In the year 1812, Mr. Charles Redheffer applied to the Legislature of Pennsylvania for a grant of funds to carry out his great invention of perpetual motion, and a committee of experts, consisting of Messrs. Henry Voight, Robert Patterson, Nathan Sellers, Oliver Evans, Archibald Binney, Lewis Wernwag, Josiah White and Samuel D. Ingham, was appointed to examine the matter.

The machine to be examined was set up in a building near the banks of the Schuylkill River, in Philadelphia, and, on a day appointed, the above-named commissioners went out to inspect the apparatus, Mr. Nathan Sellers taking with him his son Coleman, afterwards the father of Prof. Coleman Sellers, E.D.

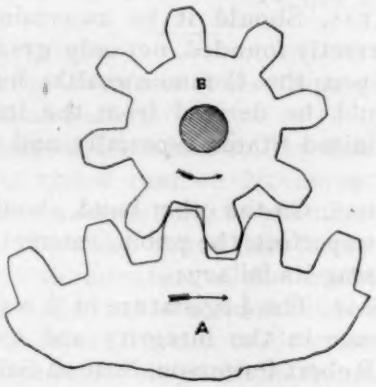
When the Commissioners arrived at the place they found that the door of the room containing the machine was locked and the key missing, so that their study was confined to an inspection of the apparatus through a barred window.

Even this limited view, however, was enough for the sharp eyes of Coleman Sellers. The machine had a set of teeth on the periphery of the rotating table, which geared into another wheel, whose axle was supposed to transmit the power to some other point where work was to be done.

Young Sellers, looking through the window, noticed that

the faces of the teeth in the two wheels were polished by wear *on the wrong sides.* This will be clear from a glance at the accompanying diagram. Let *A* be the rotating table driving the gear wheel *B*, in the direction of the arrows; then, clearly, the front faces of the teeth of *A* will press against the rear faces of the teeth of *B*, and these faces will be polished by friction.

If, however, it is the front faces of the teeth of *B*, and the rear faces of those of *A*, that are polished, it is manifest that *B* must be driving *A*. This is what young Sellers noticed, and pointed out to his father, as proving that the perpetual motion machine, instead of driving the gear



wheel, was being driven by it, from some concealed source of power.

Satisfied, by this observation, as to the fraudulent character of the Redheffer machine, Mr. Nathan Sellers concluded that others might be best satisfied by a sort of homœopathic object lesson.

He, therefore, went to Mr. Isaiah Lukens, a very skilful mechanician of that day, and had him construct the above-described model. This he exhibited at first to a number of persons, including Mr. Redheffer himself, but without explaining its true "inwardness." Mr. Redheffer was so impressed, that he privately offered Mr. Sellers a large share of his inventions if he would tell him "how it was done."

It is hardly necessary to say that this offer was declined, and that in due time the true *modus operandi* was made public.

This matter is in many respects so curious, that I will here insert a copy of the resolution, under which this commission acted, viz.:

"WHEREAS, The interference of the Legislature of Pennsylvania in causing an inquiry to be made relative to the perfection or imperfection of newly-invented machinery is not without precedent;

"AND WHEREAS, It has been represented that Charles Redheffer, of the County of Philadelphia, has invented a machine declared, not only by the inventor, but by many intelligent persons, to possess the power of self-motion;

"AND WHEREAS, Should it be ascertained that these opinions are correctly founded, not only great honor would be conferred upon the Commonwealth, but incalculable advantages would be derived from the invention by the people of the United States especially, and by mankind in general;

"AND WHEREAS, On the other hand, should the machine be found to be imperfect, the public interest would be promoted by exposing its fallacy;

"AND WHEREAS, The Legislature of this Commonwealth reposes confidence in the integrity and qualifications of Henry Voight, Robert Patterson, Nathan Sellers and Oliver Evans, of the city of Philadelphia; Archibald Binney, Lewis Wernwag and Josiah White, of the county of Philadelphia; and Samuel D. Ingham, of the county of Bucks;

"*Therefore, Resolved*, By the Senate and House of Representatives of the Commonwealth of Pennsylvania, in General Assembly met, that Henry Voight, Robert Patterson, Nathan Sellers, Oliver Evans, Archibald Binney, Lewis Wernwag, Josiah White and Samuel D. Ingham be, and they are hereby, requested to make a strict examination of the machine invented by Charles Redheffer, and to make specific representation respecting it, as its alleged importance and the public expectation require.

"*Resolved*, That the Secretary of the Commonwealth be, and is hereby, requested to transmit a copy of the foregoing

preamble and resolution to each of the persons named therein, and also to Charles Redheffer.

[SIGNED] JOHN TOD,
Speaker of the House of Representatives.
P. C. LANE,
Speaker of the Senate.

"In the House of Representatives, December 14, 1812. Read and adopted.

GEO. HECKERT,
Clerk of the House of Representatives.

"In Senate, December 17, 1812. Read and adopted.

JOSIAH A. MCJIMSEY,
Clerk of the Senate."

Then follows the certificate of the Deputy Secretary, and his letter to Nathan Sellers.

In the "History of Philadelphia," by Scharf and Westcott, Vol. I, it is stated that, on November 26, 1812, City Councils appointed a committee to examine into the Redheffer invention. It is also stated that January 21, 1813, was appointed for the examination of the machine, but, before the day mentioned, Redheffer notified the committee that it would not be convenient for him to be present; afterwards he said that he would not show the machine at all, and this being reported to the Legislature, the committee was discharged.

The champion of Redheffer in the public press of that day was the *Aurora*, as in more recent times the New York *Herald* was, of Keely.

THE RISE AND PROGRESS OF RIVER AND HARBOR IMPROVEMENT IN THE UNITED STATES.*

BY I. Y. SCHERMERHORN, C.E.

The lecturer was introduced by the Secretary of the Institute, and spoke as follows:

MEMBERS OF THE INSTITUTE, LADIES AND GENTLEMEN:

History teaches that the early centres of population have always been around the mouths of great rivers. As population, in time, spreads from such centres, the need for national intercommunication makes these rivers the natural highways of the nation. With a higher national development, and its larger requirements, the capacity of these water highways, in many cases, falls below the demand placed upon them, and their improvement to meet these larger requirements becomes a necessity.

Under modern civilization, no better material criterion of a nation's advancement can be furnished than the measure of facilities provided for ready intercommunication. By such means, the products of different parts of the country can be freely interchanged, and the varying needs of one locality met by the resources of another; while equally, if not in a larger measure, they contribute to national development by bringing otherwise widely-separated parts into closer relations, thereby breaking down provincialism, and knitting the nation together in a bond of unity, established upon national and not local interests.

The utilization for commercial purposes of the waterways of our country is so important a factor in our national growth and prosperity, that the student of political economy cannot fail to be interested in the motives which have prompted, and the steps which have led to, the present stage of development of our navigable waters; and when attention is directed to the importance of such water high-

* A lecture delivered before the Franklin Institute, December 21, 1894.

ways, in the earlier development of the country, and their still greater value to its full development under the conditions of to-day, it will readily be admitted that such national highways are not secondary in importance to any other, not even excepting our wonderful system of railroad intercommunication.

The present national policy as to the conservation and improvement, by the general Government, of the navigable waters of the United States has been the growth of a century's action and legislation; and, though this policy began with feeble indications of purpose, it has nevertheless steadily grown in force and definition, until it has culminated in the broad clear conclusions and position of the present day. While we believe that the beginning must contain all the potentiality found in the thing into which it has developed, it is frequently difficult to recognize the beginning in the end, unless we consider the intermediate stages. That you may the better compare the beginning with the end, I propose to first briefly place before you, in general terms, the position which the general Government assumes, in its broad claim of conservation and supreme control, over the navigable waters of the country, and then to trace the steps by which such a commanding position has been reached.

In earlier times, the waterways which were denominated navigable, and over which the Government assumed to exercise control, were limited to the Great Lakes and the more important waters in which the tide ebbed and flowed. Now, the term navigable waters is made, by the Acts of Congress and the decisions of the United States Supreme Court, to cover the Great Lakes and their direct tributaries, the connecting links between these lakes, and all other waters, whether tidal or not, upon which, directly or indirectly, the Government has entered for the purpose of their improvement, and which have a navigable capacity sufficient to float rafts, skiffs and saw-logs.

Over all such waters the conserving control of the Government is supreme, and without the authority of the Secretary of War, who is made, by the Acts of Congress, the cus-

todian of the navigable waters of the land, no bridge or dam can be built, or other structure erected, which would impair the free navigation of such waters; no material of any kind can be added to or taken from their beds, which will in any way modify their natural capacity, even though such additions or removals be made for the improvement of such waters by the riparian owner. For any act which will in any manner interfere with the natural condition of our navigable waters, or their navigable capacity, the authority of the Secretary of War must first be obtained.

These waters are the nation's highways, and as such are free to all, whether it be to float modern steamships, or only skiffs and saw-logs. The riparian owner may probably make some theoretical claim of ownership to its bed by erecting wharves and landings, so long as such structures in no way, directly or indirectly, invalidate the navigability of the waters; but there his privilege ends and the broad rights of the public begin, and there the National Government stands on guard over these paramount public rights. The power of Congress to guard against the perversion of the uses of a street in the city of Washington, or against any act tending to impair its usefulness to the general public, is no more supreme on such streets than it is over the navigable waters of the United States.

The accumulated force of the decisions of the United States Supreme Court, beginning with those of Chief Justice Marshall, who first outlined this policy, and coming down to those of recent times, leads to the conclusion that in this matter of the conservation and control of the navigable waters of the country, the States can in no manner exercise such control, but, instead, the power of Congress is complete, absolute and exclusive, and may be exercised to its fullest extent, and with no limitations beyond those prescribed by the Constitution.

This, in brief, is the position held by the national Government to-day, and under the conclusions which may be derived from the broad premises, this control of the Government is exercised, and the works of river and harbor improvement planned and executed. Let us now return to

the early views held upon these same questions, and trace the rise and progress toward the system of to-day, as summarized in the foregoing statements.

The fundamental English theory was, that the rivers and bays of the kingdom existed only for the purpose of floating the king's ships and furnishing salmon and turbot for the royal table; therefore, the title of all ebbing and flowing streams was in the king alone. The principle which was in force in England became equally applicable in her colonies, and the early colonial title to the waters of this country was resident in the sovereign. When the colonies revolted and finally secured their independence, each State, as a separate sovereign, maintained that it had inherited all the rights of the original sovereign, and among these, supreme control over the navigable waters within its borders.

In streams in which the tide rose and fell, low-water mark in some States and high-water mark in others, was the limit of the riparian owner's rights, and outside of such limits the State owned the bed of the stream, and, as such owner, exercised the right to lease or sell to individuals the exclusive privilege of using the State's water domain for certain purposes. Many of the Atlantic Coast States exercised these rights to very recent times, and New Jersey and Delaware still claim the right to maintain the fishing privileges sold to individuals long ago. While such rights are passively recognized by the general Government at the present time, they are not permitted to interfere with any plan for the improvement of the nation's navigable waters; and if such plan of improvement destroys the value of these rights, it is an injury without damages, since the nation's right to improve its navigable waters, or adopt any means to maintain such improvements, is paramount to any right which the State or individual may claim in such waters.

Under the "Articles of Confederation," which existed from 1777 to 1789, Congress had no power over commerce or navigation, and, accordingly, each State exacted such laws as it pleased. Rivalries existed whereby one State competed with another: one, by more favorable navigation

laws, sought to increase its own trade and commercial advantage, at the expense of sister States; and the struggle for commercial existence became simply a question of the survival of the fittest. Such a condition of affairs could not long exist, without producing the unfortunate results sure to flow from lack of co-operation and harmony, in matters which affected the body politic, and, as a result, the first amendment to the "Articles of Confederation," proposed to give Congress enlarged powers over the subject of commerce and navigation.

This early experience of the States in attempting to regulate commerce by the individual action of the States having resulted in a degraded and disorganized condition of commerce, and thereby proven a failure, upon the adoption of our National Constitution in 1789, there was, among the States, but one opinion upon this question, and that was, that "Congress should alone have power to regulate commerce among the several States." From this seemingly general and apparently indefinite provision, has grown the Government's broad assertion of power and its emphatic enforcement, over the navigable waters of the United States as it exists to-day. The power conferred on Congress to regulate commerce among the States has been repeatedly interpreted by the Supreme Court to mean that, as the greater always includes the lesser, this power includes navigation, and therefore extends to the navigable waters whereon commerce is carried. The full realization of all that was contained in this power to regulate commerce among the several States, was probably never anticipated by those who framed our constitution, and its application of to-day has been a slow evolution of policy from the environment of circumstances which have grown up around the nation in the first century of its life.

Let us now examine the early condition of affairs which surrounded the nation upon the adoption of this constitutional provision, and the efforts which were made by legislation to regulate commerce among the States. Prior to its adoption, in 1789, the States of Rhode Island, Maryland and Georgia had authorized the collection of a tonnage tax

on the commerce of some of their rivers, and the revenue derived from this tax was applied, by the States, to the removal of wrecks and other obstructions to navigation. In 1790, Congress officially gave its consent to this action of the States, for the term of one year.* By subsequent legislative action, this consent was extended yearly for some time. In 1798, a similar consent was given to the action of the State of Massachusetts, whereby Tobias Lord had been authorized to build a pier at the mouth of the Kennebunk River, and collect a duty on vessels using the pier.† In 1806, Congress gave assent to our State legislation which had empowered the Port Wardens of Philadelphia to collect a duty of 4 cents per ton on all vessels clearing from this port for any foreign place whatever; the moneys thereby obtained were to be applied to improving the Delaware River.‡

Acts of this kind were continued down to 1828, and then ceased. After 1814 it was stipulated in these Acts that this tonnage duty should not apply to vessels propelled by steam and employed in the transportation of passengers. To the beginning of the present century Congress had, except by such Acts as these, manifested no tendency to enter upon the improvement of our navigable waters, and it was from these feeble efforts of the States to help themselves, that our present policy of internal improvements has arisen.

At the beginning of this century Philadelphia, with its population of 81,000, was the most populous of our American cities, and the nation's capital; and it is of interest to note that the first appropriation ever made by Congress for the improvement of waterways, was made in 1802, by the appropriation of $30,000 for the erection of public piers in the river Delaware.‖ Since that date, $7,000,000 has been appropriated for works of improvement in the harbor, river and bay.

The early revenue of the country was small, and after

* Act of August 11, 1790.
† Act of March 27, 1798.
‡ Act of February 28, 1806.
‖ Act of April 6, 1802.

providing for the current expenses of the government, there was probably no balance to apply to other purposes; nevertheless, the importance of developing the navigable waterways seemed to have impressed itself upon Congress, and means were sought to accomplish such an object. In 1819, Congress provided that five per cent. of the proceeds derived from the sale of lands in the territory of Alabama, should be reserved and applied to making public roads, canals and improving the navigation of rivers in that territory.*

The paramount importance of the commerce of the Delaware River and Bay is again emphasized by the appropriation, in 1822, of $22,700 for the beginning of two piers in Delaware Bay, near Cape Henlopen, of sufficient dimensions for a harbor of refuge.† This was the commencement of the Delaware Breakwater, the first of its kind in the United States, and upon which work has been in progress up to the present time, by an expenditure of $2,728,000.

In 1824, the President was authorized to have surveys and estimates made of such roads, canals and rivers as he might deem of national importance, and when such surveys were finished, to report the results to Congress. This work was completed in the next year, and, apparently as a result, in 1825, the Secretary of the Treasury was authorized to subscribe, in the name of, and for the United States, to 1,500 shares of the capital stock of the Chesapeake and Delaware Canal Company, and was instructed to vote on these shares in the name of the United States, for the election of the officers of the company.‡ In 1826, similar subscriptions were authorized to the stock of the Louisville and Portland and to the Dismal Swamp Canal.‖ In these Acts, again we see the interest of Congress in internal improvements and its desire, by co-operation at least, to stimulate enterprise and prosperity through the development of navigable highways.

Although since 1804, as we have seen, small appropria-

* Act of March 2, 1819.
† Act of May 7, 1822.
‡ Act of March 3, 1825.
‖ Act of March 13 and 18, 1826.

tions had been made, from time to time, for the improvement of navigation at a few points, it was not until 1826, or during the administration of John Quincy Adams, that the first approach was made to the passage of a river and harbor bill, aggregating about $150,000 and applicable to about twenty localities.* (The river and harbor bill of 1892 aggregated about $22,000,000, and was applied to 425 localities, exclusive of surveys and examinations at 145 localities.)

From 1826 to 1838, or to the close of the administration of Andrew Jackson, Congress continued to make annual appropriations for the improvement of a number of rivers and harbors, expending, during this interval, about $9,000,000. While the number of works for which appropriations were made was not large, there is, nevertheless, evidence in these bills that the policy of improving the navigable waters of the country had been clearly decided upon, and the work inaugurated under a carefully-considered and well-devised system.

In 1841, Congress provided that to each new State thereafter admitted to the Union, 500,000 acres of public land should be set aside, the proceeds of the sale of which was to be faithfully applied by the State to the building of bridges and the improvement of roads, canals and water-courses, over which the United States should have the right to transport, free of toll, its mails, troops and munitions of war.†

After what seemed to be the inauguration of annual river and harbor appropriations, between 1826 and 1838, we find, after the latter date, a change in public policy, extending to the time of the complete re-establishment of the Union, in 1866. During this interval of about twenty-six years, only three regular river and harbor bills were passed, viz.: in 1844, 1852 and 1864. Appropriations were made in the other years, but they were small and seem to have been mainly applied to a few localities, and there to the repair and maintenance of work previously commenced. The

* Act of May 20, 1826.

† Act of September 4, 1841.

total amount appropriated, during this interval of twenty-six years, was only $6,600,000, or about 70 per cent. of the amount appropriated in the previous thirteen years, from 1826 to 1838.

After the close of the civil war, and the return of the country to peace and industrial activity, in 1866, the pent-up energy of our resources made apparent the need for improved water highways and their accompanying facilities, for the fuller development of our national growth. This era, as in other directions, marks a new departure in river and harbor improvement, and to this date, may properly be assigned the beginning of a policy, which has since steadily expanded to its present position. The importance of this period, from 1866 to the present, may better be realized through the statement that, during this twenty-nine years, about 94 per cent. of all moneys for river and harbor improvements have been appropriated.

From 1866 to 1882 inclusive, excepting only the year 1877, annual river and harbor appropriations were made, usually in yearly-increasing amounts. From 1882 to 1894 inclusive, the appropriations for the regular river and harbor bill were biennial, and passed during the even years, or the first session of each Congress. By the river and harbor act of 1890, the Secretary of War was authorized by Congress to enter into contracts for the entire completion of certain-named important improvements, under predetermined plans and estimates of cost, and to be carried on under such contracts as Congress shall, from time to time, make appropriations therefor. Since 1890, the number of works placed under these conditions has been, from time to time, increased, until at the present they number eighteen, and include such important works as the harbors of Galveston, Mobile, Charleston, Savannah, Baltimore and Philadelphia; Point Judith Breakwater, Humboldt Bay, Hay Lake Channel; and the rivers, Hudson, Great Kanawha, Saint Johns, Mississippi, Missouri, Saint Marys, Columbia, and channel between Chicago and Duluth.

After works have been placed by Congress under the provisions of these continuing contracts, appropriations

therefor are withdrawn from the regular river and harbor act, and thereafter provision is made for them by appropriations contained in the Sundry Civil Act, which is annually passed by Congress to cover liabilities previously authorized, and to be incurred during the following fiscal year. The appropriations made for this class of works, since their inauguration in 1890, is $26,331,343. The aggregate of these two classes of appropriations constitutes the amount applicable to river and harbor improvement, although provided in entirely different Acts. It is believed that this method of carrying on important works of improvement by continuing contracts, has resulted in marked economy to the nation, and advantage to the commercial interests involved; the former, arising from the ability of the government to make such continuing contracts at lower rates than would obtain under the other methods of making contracts for the expenditure of each separate appropriation; and the latter, by giving an assurance to commercial interests of the ultimate and earlier completion of the improvement. The favor with which this method of providing for the important works has been received, leads to the expectation that it will eventually be adopted upon all the principal works of river and harbor improvement.

Year.	Amount Appropriated.	No. of Works.	Year.	Amount Appropriated.	No. of Works.	Year.	Amount Appropriated.	No. of Works.
1820	9,500	2	1845	65,700	5	1870	4,197,400	98
1821	2,600	2	1846	25,000	1	1871	5,374,500	116
1822	22,700	1	1847	14,900	4	1872	5,888,000	150
1823	6,100	2	1848	65,000	2	1873	7,353,000	140
1824	115,000	3	1849	25,500	4	1874	5,228,000	142
1825	59,100	3	1850	75,000	2	1875	6,648,500	161
1826	155,400	20	1851	30,000	1	1876	5,015,000	151
1827	160,400	15	1852	2,141,300	103	1877	1,000,000	1
1828	640,100	30	1853	51,800	2	1878	8,322,700	218
1829	339,800	40	1854	291,500	5	1879	9,577,500	254
1830	357,200	25	1855	221,800	5	1880	8,976,500	340
1831	633,600	34	1856	832,100	8	1881	11,451,300	372
1832	699,300	35	1857	75,800	4	1882	18,988,900	370
1833	540,900	26	1858	87,500	3	1883	—	—
1834	774,000	33	1859	65,800	3	1884	14,948,300	316
1835	508,100	25	1860	12,700	2	1885	—	—
1836	1,157,200	77	1861	160,000	3	1886	14,464,900	342
1837	1,366,700	52	1862	115,000	2	1887	—	—
1838	1,535,500	59	1863	121,900	2	1888	22,397,600	398
1839	45,600	7	1864	647,800	9	1889	—	—
1840	1,100	1	1865	373,000	4	1890	25,136,300	436
1841	156,900	8	1866	3,881,100	57	1891	2,951,200	6
1842	187,000	5	1867	4,922,300	66	1892	22,068,200	435
1843	277,200	11	1868	1,676,500	37	1893	14,166,200	17
1844	722,600	33	1869	2,300,000	50	1894	20,043,200	408

The preceding table, compiled from the Acts of Congress, shows the amount annually appropriated, from 1820 to 1884 inclusive, for the improvement of rivers and harbors, and also the number of works, or localities, for which the appropriations were made.

The following summary of appropriations made for river and harbor improvements by decades, from 1820 to 1894, will probably more clearly present the question of their growth than any other verbal statement:

Amount appropriated	from	1820 to 1830	$1,510,700
"	"	1830 to 1840	7,618,100
"	"	1840 to 1850	1,536,900
"	"	1850 to 1860	3,872,600
"	"	1860 to 1870	14,110,300
"	"	1870 to 1880	58,604,600
"	"	1880 to 1890	91,227,600
"	"	1890 to 1894	84,365,100
Total			$262,845,900

Or, otherwise expressed, as much money was appropriated in the ten years between 1860 and 1870 as had been appropriated in the previous forty years. Between 1870 and 1880, the amount appropriated was more than twice the aggregate of the appropriations for the previous fifty years; while, for the ten years, from 1880 to 1890, the appropriations were 60 per cent. more than those of the previous ten years, and in excess of the aggregate for the previous sixty years. From the amount already appropriated in the present decade and the ratio furnished by the past, it seems fair to assume that, by its end, the appropriations will have reached, for this decade, fully $200,000,000. With such a policy applied to such possibilities as we have, who can say what the next fifty years will produce in their feature of river and harbor improvements?

The planning and execution of these works of river and harbor improvement is a part of the duty of the Corps of Engineers of the Army, which is practically a bureau of the War Department, of which the Secretary of War is the head. In this work the entire country is divided into five divisions, viz.: the Pacific, Northwest, Southwest, Northeast

and Southeast; and over each is placed one of the senior officers of the Corps, usually with the rank of Colonel, in the capacity of Supervising Engineer. These five divisions are further subdivided into from forty-five to fifty districts, each in charge of an officer of the Corps, and generally known as the local Engineer-in-charge of river and harbor improvement. The official head of the Corps is the Chief of Engineers, with the rank of Brigadier General.

Plans and projects for improvements, with estimates of cost, and also all reports upon examinations or surveys called for by Congress, are submitted by the local engineer of each district to the Supervising Engineer of the division, by whom they are transmitted to the Chief of Engineers, with such comments as, in the judgment of the Supervising Engineer, may be necessary. At least once in each year, the Supervising Engineer visits each district in his division and, accompanied by the local Engineer-in-charge, makes a careful inspection of all works in progress.

Upon the works of river and harbor improvement there are now engaged, exclusive of the Chief of Engineers, about 77 officers, with the following rank, viz.: 6 Colonels, 9 Lieutenant-Colonels, 15 Majors, 18 Captains, 21 First Lieutenants and 8 Second Lieutenants. The Second Lieutenants of the Corps, after being graduated from a four years' course at West Point, are assigned to a post-graduate course of three years at Willetts Point. This course is essentially a school of practise under the tuition of officers of the Corps, in which the young engineer is taught to co-ordinate his theoretical knowledge with its practical application to the arts of fortification, defenses, and river and harbor improvements. As a further preparation for active practise, he is often subsequently assigned to duty under a senior officer as an assistant upon constructive works, thereby passing through a novitiate, which well prepares him for the active practise of his profession.

The administration of the works of river and harbor improvement requires the employment of large number of civilians, in the capacity of assistant engineers, surveyors and draftsmen; and a large and able body of men has been

drawn from the civil engineers of the country to fill these positions. To supply the increasing demand for such service, nearly all of our engineering schools have introduced into their courses, instruction relating to river and harbor improvement.

The method of carrying on these river and harbor improvements at the present time may be summarized as follows: Congress having previously made appropriations for works in certain localities, we find these works in progress. At the close of each fiscal year, the local engineer of a district submits, through the Supervising Engineer of the division, to the Chief of Engineers, a report upon each work in his district, embodying statements as to the project under which the improvement has been carried on, details of work done, with recommendations for work further proposed under the project, together with a statement of the amount of money which can profitably be expended in the fiscal year following the one upon which he is entering.

Upon the receipt of these reports, they are transmitted to the Secretary of War, by the Chief of Engineers, with a report on each work containing such recommendations as he deems proper, and with a statement of the amount of money required for continuing the work through the year for which appropriations are yet to be made. These combined reports are then submitted to Congress by the Secretary of War as a part of his annual report.

During the sessions of Congress, these reports are carefully considered by a committee in the Senate known as the "Committee on Commerce," and in the House, as the "Committee on Rivers and Harbors," and a bill, denominated "An act making appropriations for the construction, repair and preservation of certain public works on rivers and harbors and for other purposes," is finally drawn and passed by Congress, and approved, or otherwise, by the President.

This bill contains specific amounts for each work named, sundry legislation pertaining to navigable waters, such as has been previously alluded to, and a list of new localities for which Congress directs preliminary examinations or surveys to be made. No new works of improvement can be

undertaken until an appropriation has been specifically made therefor, and such appropriations cannot be made until the local engineer has made a preliminary examination, and, together with the division engineer, shall have reported to the Chief of Engineers that in their judgment the river, harbor, or locality, under examination, is worthy of improvement by the Government, with reasons and facts for such opinion, and the present and prospective demands of commerce for such improvement: and further, if worthy of improvement, what it will cost to make a survey of the same, with the view of submitting a plan for its improvement, with an estimate of the cost thereof. The Chief of Engineers is required to submit to Congress, through the Secretary of War, all such reports of the preliminary examination, together with his views thereon, and his opinion of the public necessity or convenience to be subserved by the proposed improvement.

Should the river, harbor or locality have sufficient merit under all these requirements to run this triple gauntlet successfully, Congress, if it approves, may order a survey to be made, the results of which are, in a similar manner, transmitted to Congress, with a detailed plan of improvement and estimate of cost, as determined from such a survey. Should this survey justify the previous opinion held at the time of the preliminary examination, Congress may, at its next session, make an appropriation for commencing the improvement. This method results in the survival of the fittest, and prevents the expenditure of public moneys upon localities that have no merit as public improvements.

Having briefly followed the rise and progress of river and harbor appropriations, and the method of their application, let us turn to some of the leading principles which have been developed by legislation upon the subject of the navigable waters of our country.

Although the policy of improving our navigable waters by government appropriations dates back to nearly the beginning of this century, there was until lately little, if any, legislation by which the right of the Government was claimed to conserve and control its navigable waters. Leg-

islation of this class has been enacted mainly during the past ten years.

The legislation which is of most interest and which best illustrates the general position which the Government has assumed in the entire question, is that relating to its broad denial of the right of any individual, corporation or municipality, city or State, to in any manner interfere with the free and safe navigation of any navigable waters of the United States, without the consent and authority of the Government.

No bridge can be built across, or abutments placed in, such waters prior to the approval by the Secretary of War, of the specific plan and location proposed for such bridge.* This supervision regulates the length of fixed spans, the width of draw-span openings, the clear height under the bridge and the position of the abutments. After the bridge is completed, the same authority prescribes rules and regulations governing the opening of any draws therein for the proper passage of vessels, and imposes heavy fines and penalties for their infraction.† Bridges previously built, and which are found to obstruct navigation, are required to be altered upon notice by the Secretary of War, so as to render navigation through or under such bridges safe, easy and unobstructed.‡ Any bridge which presents difficulties to navigation, or to passage of rafts through its draw or raft-spans, shall be provided with satisfactory aids to the passage of such spans.‖ In the matter of water, gas or oil pipes, laid across the bed of any navigable waters, these, in like manner, are subject to the control and authority of the Secretary of War.

The Secretary of War has authority, in any waters which he may consider it desirable, to establish harbor lines, beyond which no piers or wharves shall be extended or deposits made, except under such regulations as he may prescribe from time to time; and no wharves, piers or other con-

* Acts of September 19, 1890; July 13, 1792.
† Act of August 18, 1894.
‡ Acts of August 11, 1888; September 19, 1890.
‖ Acts of July 5, 1884; August 11, 1888.

structions can be placed in any navigable waters where such harbor lines have not been established, except by permission of the Secretary of War;* all structures previously placed, and which obstruct or impair navigation or commerce, are declared by the Acts of Congress to be unlawful structures.† In mining districts, deposits or dèbris of mines or stamp work, can only be deposited in, or in the vicinity of, navigable waters, within limits to be prescribed for each case.‡

So jealously is this exclusive right of the Government regarded and exercised, that any alteration or modification of the natural capacity of any navigable waters, is forbidden without the previous authority of the Secretary of War, even though such alteration or modification might be for the absolute improvement of the waters.‖

Any wreck, sunken vessel or cargo, which for the period of sixty days has been permitted by its owners to obstruct or endanger navigation, can be destroyed and removed by the Government, and the owner thereof will have no claim for damages arising from the destruction of such wreck, vessel or cargo. Should any parts of the vessel or cargo, after being removed, have any salable value, the amounts derived therefrom are turned into the treasury of the United States.§

The constructive works of improvement are guarded with as much care as the waters in which they are placed; and by the Acts of Congress it is made unlawful for any person to build upon, alter, injure, or in any manner impair, the usefulness of any sea-wall, bulkhead, jetty, dike, levee or other construction; or to remove or change any boundary mark, gauge, surveying station, buoy or other established marks of the United States.¶ Where the Government requires material for constructive purposes upon its public works, it may take such material from bars and islands, or

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* Acts of August 11, 1888; September 19, 1890.

† Acts of September 19, 1890; July 13, 1892.

‡ Act of August 5, 1886.

‖ Acts of September 19, 1890; July 13, 1892.

§ Acts of June 14, 1880; August 2, 1882; September 19, 1890.

¶ Act of September 19, 1890.

other localities adjacent to such works, upon the payment of a fair compensation to the owners of such material.*

In the improvement of any navigable waters, the Government may close subsidiary channels, or in any manner considered necessary for accomplishing the desired improvement, divert the natural channel into new positions; and channels, or areas behind islands or bars, may be filled up. For any injury which may result to riparian owners from such diversion of the natural channel, or filling of channels and areas, there is no recourse at law; and his injuries, if any exist, belong to the class denominated "*damnum absque injuria*," or damage without responsibility. For any land or other property which may be required to carry into effect desired improvements, the Government can, if it desires, exercise the right of eminent domain, and so acquire title by condemnation proceedings.

This now declared and fully exercised right of the Government to conserve and control the navigable waters of the country, has been mainly brought about through the legislation of the last ten years; and, though so long delayed in its application, was nevertheless, all latent in that provision of the Constitution which gave Congress "the right to regulate commerce among the States." When we revert to the earlier position of the Government upon these questions, and note in the beginning its feeble application of inherent rights, the contrast between the past and present becomes very marked, and the progress toward absolute control very decided.

With the grand possibilities which are inherent in our waterways as a basis, with a policy so evidently directed to the full utilization of these possibilities, and with the best professional ability in the world to execute, there is every reason to anticipate that the near future will give this country a system of river and harbor improvements which will be the most extensive and complete in the world, and fully commensurate with our wonderful development along all other lines of national progress.

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* Acts of July 5, 1884; April 24, 1888.

There is another consideration connected with this subject that demands passing attention, and which has had and will continue to have, a strong bearing upon the question of river and harbor improvement. While these improvements have been in progress during the past thirty years, there has been a constantly-increasing demand for greater channel depths and widths, arising from the changes which have ensued in vessel building and the increased draft of such vessels. In 1858, when the (then) phenomenal *Great Eastern* was launched as the wonder of the world, she had a draft of twenty-five feet, and but one harbor in the United States, that of Portland, Me., had sufficient depth over its entrance bar at low tide to safely admit the giant. A few weeks ago many of my auditors may have witnessed the launch of the steamship *St. Louis*, with a loaded draft of twenty-seven feet, from Cramp's ship yards on the Delaware, and beyond passing notice and the feeling of justifiable pride over the success of Philadelphia's enterprising ship builders, the event was almost unnoticed.

Thirty years ago the dimensions and draft of ocean vessels was such that our great seaports of Boston, New York, Philadelphia, Baltimore, Norfolk, Charleston, Savannah and New Orleans, only required an entrance depth to their harbors of from eighteen to twenty-two feet at low water. To-day, ocean commerce demands depths in our channels and harbors of from thirty to thirty-five feet to meet the requirements of the modern ship's draft, and there is no reason to anticipate that the maximum requirements of channel and harbor depths have been reached.

The difficulties which confront the engineer, as well as the cost of the improvement, are increased far beyond the simple ratio of the increased requirements for the greater depths. Since in the past, our American engineers have so successfully met and overcome the obstacles of Nature in our great water highways, as well as the larger demands upon their skill arising from increasing requirements, so, in the future, we may feel assured that with enlarged experience and added resources they will ever stand well ahead of all demands upon their professional skill.

Time, and the proper limits of my subject, forbid any account of the works of river and harbor improvement which have already been accomplished by the application of moneys appropriated and the engineering skill which has been applied. Without invidious comparison with other and less prominent works, but which demanded no less care and skill, may be mentioned the improvements already accomplished in New York harbor by the removal of Gedney's channel bar and the rocky reefs at Hell Gate; the Delaware River, with the Breakwater at one end and Philadelphia harbor at the other, with a large number of intermediate points; the harbors of Baltimore, Savannah, Charleston, Mobile and Galveston; the rivers Hudson, Great Kanawa, Tennessee, Cumberland, Ohio, Mississippi, Missouri and Columbia, and the great works in the Sault Ste. Mary.

When a comparison is made between such works, and those undertaken or executed abroad by European engineers, we have every reason to turn with pride and satisfaction to our own results, and are justified in the claim that our own land not only furnishes many examples of the best modern practise and success, but equally, that our American engineers, if not already leaders, are at least the peers of their European brethren.

As population increases, better facilities must be furnished for water transportation; results already accomplished must be expanded, and still other new works of river and harbor improvement undertaken; and as new centres of population arise and expand, there must be a corresponding expansion of their commercial facilities. The possible demands of the future point toward a development of our present system of river and harbor improvement into something almost beyond suggestion.

Nationally, our development and progress have been so rapid in all directions as to be phenomenal, and so many evidences of this progress lie around us, that we naturally fail to note, except that which is nearest and which affects our personal environment. The subject which has been presented to you this evening may be one of the more

remote and obscured evidences of our progress, but, nevertheless, I feel assured that the rise and progress of river and harbor improvement is entitled to a place among the witnesses which are testifying to our national development.

THE NATURAL SODA DEPOSITS OF THE UNITED STATES.*

BY DR. THOS. M. CHATARD.

The lecturer was introduced by Dr. Samuel P. Sadtler, Professor of Chemistry in the Institute, and spoke as follows:

MEMBERS OF THE INSTITUTE, LADIES AND GENTLEMEN:

Natural soda is the residue obtained by the evaporation of natural alkaline waters without the aid of artificial heat. It is composed of sodium carbonate and bicarbonate in varying proportions, mixed with impurities, mainly sodium chloride and sulphate. It is found to some extent in all dry regions, such as Hungary, Egypt and the deserts of Africa and Asia; but Nature has been especially bountiful to the United States in giving us a most valuable source of national wealth in the despised and detested "alkali dust" and "alkali water" of the Great Basin.

In its crude condition natural soda has been collected and utilized from the earliest times; but until its nature had been studied and proper methods of purification devised, the alkaline carbonates contained in it could not be obtained sufficiently pure and cheap to compete with the artificial product. Now that the technology of natural soda is fairly well understood, we may expect that the attention of capital will be drawn to the possibilities of this industry, the slender beginnings of which may be seen at a few places in the West.

The ancient Egyptians, who seem to have known every-

* A lecture delivered before the Franklin Institute, February 23, 1894.

thing that was knowable in their time, made much use of a substance which they called "neter."

The Bible describes "neter" as a solid substance, having cleansing properties, and as effervescing with vinegar. This was obtained from certain lakes and pools in the Egyptian deserts, and became at a very early date an important article of commerce.

The myth of the discovery of glass is interesting to relate at this point: Some Phœnician sailors, landing on a sandy shore, could find no stones large enough to support their cooking pots, and were compelled to use some lumps of the "neter" which formed a part of their cargo. The next morning they found that the heat of the fire had melted the "neter," which, fusing with the sand of the shore, had formed a glass. Of course, a true glass could hardly be formed in this way, as vitrification requires a high degree of heat, but the alkaline silicate thus produced is today used in large quantities and for many purposes.

The Greeks, becoming acquainted with this "neter," called it "nitron," and the Romans Latinized this to "nitrum." From the Latin is derived our English word "nitre," which we apply to an altogether different class of salts—the nitrates—and especially to the potassium nitrate, or saltpetre. Saltpetre, indeed, being a natural product and similar in appearance, was generally confounded with the true "nitrum" or crude natural alkaline carbonate, and the distinction between them appears first to have been made by the Arabs, who introduced the words "natron," "kali" or "alkali," and even "soda." From "natron" we get the word "natrona," and also the name "trona," usually given to the natural carbonate.

It must be remembered that, until the invention of gunpowder, there was no special demand for nitrates, while the need of cleansing materials, not only for domestic purposes, but also for the elaborate religious ceremonies of the ancients, made the preparation of some sort of soap a necessity of the earliest civilization. We need not be surprised to find that chemistry had its beginning in the collection, preparation and use of the "neter," or, as we now call it,

"natural soda." Moreover, the human race is supposed to have originated in Mesopotamia, while the earliest records of civilization are to be found among the Egyptians. Now, all these regions are arid in their climate and throughout their extent we find occurrences of natural soda. A knowledge of its properties and uses must have been early acquired, and must have accompanied the tribes in their subsequent wanderings. That wood ashes had similar properties would also be naturally discovered, and in time the value of the ashes of other plants, which of themselves are not especially valuable as fuel, would lead to the production of those crude alkaline carbonates which, under the names of "rocheta," "salicor," "varec," "kelp" and "barilla," have held their place in commerce almost down to the present day. The supply of such crude ashes is always uncertain, and their composition continually varies; hence, they have gradually been supplanted by the artificial alkalies, as these became purer and cheaper through the development of the Leblanc soda process.

We now come to an interesting case of the struggle for existence and survival of the fittest, exemplified by the history of the alkali trade. As our time is short, we cannot stop to consider the processes of artificial soda-making, further than to say that the great development of manufactures during the latter part of the last century, through the invention of machinery for spinning, weaving, etc., caused an enormous increase in the demand for alkalies, while at the same time the progress of civilization was tending to decrease the supply of the crude natural ashes. Under these conditions the price of crystal soda, which, at present, is about $15 a ton, was, in 1809, over $350; kelp, containing only three per cent. of soda, selling at the same time for $55 a ton (Lunge, Vol. II, p. 297).

These high prices stimulated chemical research, particularly as it was already well known, though no manufacturing process had yet been devised, that soda could be made from common salt. Much money and the time of many men were expended upon this problem. The glory of the successful solution of the problem, is due to the man who, as

Professor Lunge says, "is probably the most celebrated name in chemical technology"—NICHOLAS LEBLANC. On September 25, 1791, Leblanc obtained a patent in which his process is plainly set forth, and its essential features have remained unchanged up to the present time. These are: the treatment of common salt with sulphuric acid, producing Na_2SO_4 and HCl; in the fusion of the sulphate with coal and $CaCO_3$, producing black ash; the leaching of the black ash and the extraction of the alkali thus formed.

Leblanc was ruined by the French Revolution, and, becoming insane, committed suicide in 1806. The success of his process, however, had been established, and its operation steadily extended. A great increase in the chemical industry of Great Britain followed as the result of the abolition of the salt tax. In 1823, this tax amounted to the enormous rate of £30 or $150 per ton, but was then greatly reduced, and entirely abolished in 1825. England at once took the lead in chemical industry, which, in many departments, she has maintained until now.

Within the past twenty years, the ammonia-soda process, as developed by Solvay and others, has become a sharp competitor of the Leblanc process. In the ammonia-soda process, a strong solution of common salt is treated with ammonia and carbonic acid; sodium bi-carbonate is formed, and, being comparatively insoluble, precipitates and is filtered off. The ammonia is recovered from the filtrate, the whole of the chlorine of the salt being lost as calcium chloride. It is this loss that prevents this process from completely superseding all others. The Leblanc process only exists because it can utilize this chlorine, in the form of bleaching powder, chlorates, etc. As soon as the chlorine of the ammonia process can be recovered in an economical manner, the Leblanc process must disappear, and it seems that this must soon be accomplished.

But, in the moment of its triumph, the ammonia process is threatened with new and younger opponents. One is the electrolytic method of decomposing common salt; the other the natural soda, which is the subject of this evening's lecture. What, in the opinion of experts, is likely to be

the effect upon the alkali trade, of these new sources of production, can be shown by a quotation from a paper, by that eminent authority, Professor Lunge, of Zurich, entitled "The Progress of Chemical Industry in Europe in 1892," and published in "The Mineral Industry for 1892."

Speaking of the struggle between the Leblanc and ammonia-soda processes, and the reported success in utilizing the chlorine of the latter, he says:

"Supposing, however, that the Leblanc people are not to be killed by the blow threatening from that side, their doom is evidently sealed in another direction. After a long series of failures, some of the processes for making chlorine by electricity now seem to be securely established. We shall not discuss the question, which of them may be the best in the field; but it is certain that in some quarters all difficulties have been finally overcome, and that all other old or new chlorine processes will soon be out of favor. We poor Europeans may well tremble, as we think of the enormous advantages for all applications of electricity enjoyed by the United States, with their unbounded water-power, coal fields and oil wells, not to speak of natural gas. In all human probability, they will soon cease to be importers, and may even become exporters, of bleaching-powder.

"The electrical processes are certainly far greater sources of chlorine than of alkali. They produce from common salt, for every ton of bleaching-powder, only half a ton of soda ash, or one-third of a ton of caustic soda. The bulk of the alkali must, therefore, be supplied from other sources, undoubtedly at first in the form of ammonia-soda. But here, again, the mineral wealth of the United States is evidently destined to prove fatal to the old processes. There can be no doubt that the immense quantities of natural soda, shown to exist in the Californian and other soda lakes, will not be allowed to lie dormant any longer. If those lakes are once worked with the energy which is otherwise not wanting in America, the days are numbered when Liverpool soda will rule in the New York market."

Strong as this statement is, there is no reason to doubt

its correctness. When that day comes; when the natural soda of the United States shall have conquered a dominating position in the markets of this country, Nature will have avenged the defeat which she met with, when the barilla and kelp industries were killed by the art of man. The result will be far-reaching, and will work a complete revolution in chemical industry; for this, in great part, is based upon the manufacture of alkali, with its numerous ramifications, each having its special products. The salt, sulphur and ammonia trades will undergo important modifications, and, while some forms of industry may disappear, others will take their places.

The chemical industry of the United States, except in the line of drugs and fine chemicals, has not been developed, in volume or variety of products, to the extent warranted either by our natural resources, or by the ability and enterprise shown by the Americans in other branches of manufacture.

The large demand for sulphuric acid in the fertilizer and oil-refining trades, could, of course, be met by home production only, since transportation of such material from abroad is practically impossible. The sodium sulphate, obtained from the nitre-cake of the sulphuric acid works and from the salt-cake of the muriatic acid makers, is utilized for glass-making, most domestic attempts to convert it into alkali by the Leblanc method having apparently failed of commercial success. Almost all of our demands for alkali, and practically all of our needs for bleaching-powder, chlorates, and the other products of the Leblanc process, have been met by importation from abroad.

The Pennsylvania Salt Company has, by the use of cryolite, been an extensive manufacturer of soda for many years, while, about ten years ago, the Solvay Process Company established its works at Syracuse, N. Y., and has developed a large business. Other forms of the ammonia-soda processes are beginning, or preparing to begin, to share the field; and it is likely that before long the home demand for alkali can be met by ourselves, even if no use is made of the natural soda, of whose great future Professor Lunge speaks so decidedly.

Now, without trenching upon matters of private business, I can say that there is every prospect that before long arrangements will be perfected by which very extensive operations for the development of our natural soda will be started. If some former plans to this end have miscarried, it has not been because of any uncertainty as to the nature or extent of the supply, or because of any great technical difficulties in the manufacture of the market products. All of these matters have long since been settled, but capital is naturally conservative and is reluctant to enter upon new paths, particularly when the quantities to be dealt with are so enormous. The figures which I shall give you may sound almost extravagant, but be assured that they are much short of the truth; and now, without further delay, I shall give you some idea of a small part of our natural wealth.

From the remotest times of antiquity, the people of Egypt have used the salts gathered from a number of small lakes which are situated in the desert of St. Macarius, about sixty miles northwest from Cairo and about thirty-six miles from the Nile. According to Sickenberger, who lately examined this locality for the Egyptian Government, these lakes are sixteen in number, but only one is now worked for the salt. The surface of these lakes varies with the season, being lowest when the Nile is high, and highest when the river is low. This shows that the lakes are fed by the infiltration of the river water, which naturally takes a considerable time to pass over the intervening distance. The soil of the surrounding country is composed of alternating layers of limestone, ferriferous clay and calcareous sandstone; and in the clay are many crystals of gypsum and rock-salt, sometimes aggregated into layers. The water of the lakes contains sodium chloride, sulphate and carbonate in varying proportions; and, by spontaneous crystallization, a product is obtained which contains as much as sixty per cent. of sodium carbonate.

These lakes, being so long known, have frequently been visited and investigated by scientific travelers, and many hypotheses as to the mode of origin of the alkali have been

offered. Our time will only allow us to touch very briefly upon this matter; but a few words, at this point, will better enable us to appreciate the causes of the existence of our western alkali.

It must be understood that the soil around these lakes does not show the presence of alkali to any appreciable extent. Now, it has long been known that if a mixture of common salt (or sodium chloride), gypsum (or calcium sulphate) and limestone (or calcium carbonate) is moistened and exposed to the action of the air, the mass, which is at first neutral, soon begins to show an alkaline reaction on account of the formation of sodium carbonate, so that in time this new substance can be extracted from the mass by leaching. Until Sickenberger's visit, it had been supposed that the soda found in the lakes was formed in the soil in the manner just described, leached out by the water and thus conveyed to the lakes. He made the remarkable observation, however, that the water of the springs which feed the lakes is perfectly neutral, showing large amounts of sodium sulphate, but no carbonate. As soon, however, as the spring water reaches the surface and comes in contact with plant-life, the sulphate begins to decompose, giving off sulphuretted hydrogen, and being converted into sodium carbonate, the water becoming alkaline in reaction. As the lakes have no outlet, the inflowing water has no means of escape except by evaporation, leaving its salts behind; hence, the amount of carbonate in the lakes is continually increasing and the annual crops never fail.

While this is a very typical case of one mode of formation, there is another which is probably even more important. The existence of springs carrying sodium carbonate is well known, since many of them have a world-wide reputation for their medicinal qualities. Although most of them are weak solutions, a comparison of their compositions with those of the waters to be described will show that, by evaporation, they would yield a very pure natural soda. The sodium carbonate in such springs is produced by decomposition of the alkali-bearing rocks through which the water flows, and this decomposition is brought about by the combined action of

air and moisture, aided in many instances by heat and pressure.

The air absorbed by water contains a much larger proportion of oxygen and carbonic acid than the normal atmosphere. The composition of these dissolved gases may be taken as—

nitrogen, 79·00 per cent.; oxygen, 20·95 per cent.;
carbonic acid, 0·04 per cent.,

while, according to Bunsen, the air absorbed by water at 15° C. (60° F.), contains—

nitrogen, 63·62 per cent.; oxygen, 34·12 per cent.;
carbonic acid, 2·26 per cent.

The alkali-bearing minerals are generally silicates, having for bases ferrous or ferric oxide, alumina, lime, magnesia, soda and potash, in proportions varying according to the character of the mineral. By the action of water, containing CO_2, upon such minerals, the alkalies and alkaline-earths are converted into carbonates and dissolved in the carbonated water. Hence, they are leached out of the residue, which is rendered the more porous by the decomposition, and if the water so charged does not, on its way to the surface, meet with the chlorides or sulphates of other metals, which, by double decomposition, would produce alkaline chlorides, or sulphates, and non-alkaline carbonates, then the alkaline carbonates make their appearance as constituents of a mineral spring. In such springs the salts of sodium are usually in much greater proportion than those of potassium, not only because the soda minerals are in general more easily decomposable, but also because soils have a strong tendency to take up and retain potash salts from water percolating through them, while readily giving up any soda salts which they may contain.

If such spring or drainage waters flow into basins without outlet, and the rate of evaporation equals the inflow, a concentrated solution gradually results, and, if the inflow be interrupted, we shall, in time, have a dry basin in which the salts have deposited as a crystalline mass. It is evident that if the geological character of a country is favorable to the production of such alkaline waters, the dryness of the

climate, or the excess of evaporation over rainfall, determines the degree of concentration of the basins, the number and extent of which are dependent on the topography.

An arid climate is characteristic of many parts of the globe, hence there are numerous localities where pools and dry deposits of natural salts exist. The desert region of northern Africa, from Egypt to the Atlantic Ocean, the high plateaux of Armenia and Central Asia, the plains of Hungary and many portions of South America, abound in occurrences of these salts; while the lake of Tescuco, near the City of Mexico, has yielded natural alkali since long anterior to the time of Cortez. But all these sources of possible supply, taken together, sink into insignificance when compared with those of the United States, whether we consider their absolute magnitude and extent or their prospective importance.

In describing the localities within the boundaries of the United States, only the more important ones will be considered. Throughout the entire region which stretches from the Rocky Mountains to the Sierra Nevada, the climate is excessively dry, and only a small portion of the scanty annual rainfall finds its way to the sea. The rest either evaporates at once or drains into enclosed valleys. In the Great Basin, almost every valley has, in winter, its shallow lake of drainage water, which, in summer, more or less completely dries up, leaving behind a layer of salts. These are the "alkali flats," of which you have all heard, and which often stretch for miles, resembling new-fallen snow, and producing a glare well-nigh insupportable under that cloudless sky and burning sun. The arid soil of these plains supports a very scanty vegetation, and the winds drive before them dense clouds of dust heavily impregnated with "alkali," causing great annoyance to the traveler, even when he is a partaker of all of the advantages and luxuries furnished by Mr. Pullman. It may be well to note that in the West the term "alkali" means natural salts of every sort, which form upon the surface of the soil, or around the margins of pools. These salts are mostly mixtures of sodium salts, such as the chloride, sulphate and carbonate, and in

general it may be said that sulphate predominates on the eastern side of the region; chloride in the central portion, as in the Great Salt Lake; while the more valuable carbonate is found still further west, along the eastern slopes of the Sierra Nevada.

As seeing is believing, I will now ask you to accompany me on a trip from Omaha to San Francisco, *via* the Union Pacific Railroad, as the principal localities which yield natural soda can be reached by this line. Taking the Pacific Express at Omaha, in the evening, we reach Laramie, Wyo., twenty-four hours later. From Laramie a branch road runs nearly due south, thirteen miles, to the Soda Lakes, or, as they are usually called, the Union Pacific Lakes. Only one of these lakes usually contains water, the others, except in wet seasons, being dry deposits. The deposits are quite thick, being in some places 11 feet deep, and extend over hundreds of acres. The Downey Lakes, a few miles west, are similar in all respects and are equally extensive.

The salts in these lakes are sodium sulphate and chloride, the sulphate greatly predominating. The total amount of sulphate that can be obtained here is enormous, and it is often very free from other salts. As the Western demand for caustic soda is large, it was natural to suppose that it could be profitably made from this sulphate by the Leblanc process, particularly as the first stage of the process—the making of the sulphate—has already been performed by Nature. Repeated attempts have been made and much money has been spent to accomplish this, but so far without commercial success. The principal cause of failure is the large proportion of water in the sulphate. Its composition is that of Glauber's salts, or crystallized sodium sulphate, containing ten molecules of water of crystallization, or nearly fifty-six per cent. of the total weight. Before the sulphate can be converted into the "black ash" of the Leblanc process, this water must be got rid of—an operation which has proved so expensive as to destroy all reasonable expectation of profit. While the opinions of the best authorities hold out little hope that this sulphate can be profitably utilized in the near future, whoever can find

a satisfactory solution to the problem must reap a rich reward.

On the line of the Union Pacific Railroad, and 136 miles west of Laramie, is Rawlins; and 50 miles north of Rawlins lies the Sweetwater Valley, in which are the Dupont Lakes. These are four in number and differ from the Laramie Lakes in containing a considerable proportion of sodium carbonate. For this reason, and because coal and limestone are reported to exist near-by and in ample supply, a flourishing industry may here be built up whenever the transportation facilities have been developed. Continuing along the road from Rawlins, we see many patches of alkali, which, however, contains little or no carbonate, and, passing through the beautiful Echo Cañon, we reach the Great Salt Lake. This is a dense solution of common salt with much sulphate. In winter the latter crystallizes out in large quantities along the shore, and some attempts have been made to utilize it, but, so far as I have heard, the results have not been favorable.

From Great Salt Lake, another day's journey, during which we observe an increasing number of alkali flats, brings us to Wadsworth, Nevada. From this point we proceed by wagon southward toward the sink of the Carson River. The entire journey is through a very arid region, the latter portion being a sandy waste on which even sage brush can hardly grow. After twenty miles of a terribly hot journey, we reach a place called Ragtown, consisting of a house and a well. I do not know much about the house, but the well is good.

Ragtown, though now deserted, has a history, and was a place of much importance before the advent of the transcontinental railway. It was the long and greatly desired goal of the emigrant, who, having painfully toiled through the deserts of Utah and Nevada, could, when he beheld the tents of Ragtown and the green banks of the Carson, at last feel sure that the danger of death, by starvation and thirst, was over. Tired and ragged, with worn-out cattle, he there met traders from California, from whom he could obtain fresh oxen and fresh clothes. Poor as the emigrant's cattle

might be, they still had some value in barter, since, after recuperating in the valley of the Carson, they could be sold to later arrivals; but no one wanted the old clothes, so these were cast to the winds, and by their picturesque plenty and confusion gave to the great emporium the euphonious name of Ragtown. Its inhabitants, its glory, even its rags, have departed. Its name would perish were it not for the remarkable natural occurrences which exist near-by, and which are known as the Big and Little Soda Lakes.

[*To be concluded*]

A REMARKABLE ELECTROLYTIC PHENOMENON.*

By C. J. Reed.

Most metals, when used as positive electrodes in electrolysis, are either dissolved or corroded, producing metallic salts or oxides; but when used as negative electrodes, metals do not generally undergo such corrosion. They are seldom affected in any way, chemically, by the action of the current, and are never dissolved.

It is to what appears to be an exception to this rule, that I wish to call your attention this evening.

While experimenting, some time ago, on the oxidizing effect of various electrolytes upon lead electrodes, I noticed, accidentally, that under certain circumstances, lead behaves toward some electrolytes in a very peculiar manner. The only conditions required are that the electromotive force and current density shall be very high.

On passing an electric current through a solution of disodium-hydrogen phosphate, between electrodes of sheet lead, I noticed nothing unusual during the experiment. The solution had a very high resistance and very little current passed even with a high electromotive force. At the close of the experiment, there being no switch in the circuit, the current was interrupted by lifting one of the elec-

* Read at the stated meeting of the Electrical Section, February 27, 1895.

trodes out of the solution. It happened to be the negative electrode.

At the instant of final contact between the electrolyte and the lowest point of the electrode, as it left the solution, I noticed what appeared to be a cloud of black smoke, or precipitate, which had suddenly formed in the solution. On examining the cloud more particularly, and repeating the experiment several times, I found that by exposing only a very small surface of the negative electrode to the solution, there was produced a voluminous cloud of dark blue or lead-colored precipitate, which rapidly sank in the solution and rendered it entirely opaque.

It was then observed that the lead cathode was being rapidly eaten away, and that the precipitate was being produced at the expense of the lead. The precipitate was collected on a filter, washed with water and alcohol, and dried. It was found to be an impalpable powder resembling lead, and permanent in the air at ordinary temperatures. When rubbed in an agate mortar, it was reduced to a lustreless gummy mass, but did not assume a metallic appearance. Heated to the melting point of lead in the open air, it suddenly absorbed oxygen and formed yellow plumbic oxide, with incandescence. Heated in a glass tube in absence of oxygen, it melted to a globule of metallic lead.

In this bottle I show you a sample of this product that has been preserved more than two years without any apparent change.

The surface of the lead cathode, after the experiment, exhibited a peculiar appearance. It was reduced to a point at the end, and presented a smooth, shiny surface, like polished lead. It was of the form we should expect to find a positive electrode of copper or other soluble metal.

Other electrolytes were tried and it was found that the lead precipitate could be produced in the following solutions:

Potassic sulphate,
" hydric sulphate,
Sodium orthophosphate,
Di-sodic-hydric phosphate,
Sodic-di-hydric phosphate,
Magnesic sulphate,
Calcic sulphate,
Aluminic sulphate,
Ammonic oxalate,
Sodium hypophosphite,
" sulphide,
" thiosulphate,
" sulphite,
" chloride,
Potassic chlorate.

Potassium sulphocyanide,
" ferrocyanide,
" ferricyanide,
" iodide,
" bromide,
" carbonate.
Calcic chloride (with difficulty),
Strontium sulphate,
Manganous chloride,
Sodium borate,
Potassium acetate,
Ammonium hydrate,
Hydric phosphate,
Ammonic sulphide,

The precipitate could not be produced in solutions of the following substances:

Barium hydrate,
" chloride,
Calcium hydrate,
Ammonium carbonate,
Strontium nitrate,
" chloride,
Hydric sulphate,

Hydric acetate,
" oxalate,
Ammonic acetate,
" nitrate,
" chloride,
Potassium bi-chromate,
" nitrate.

The precipitate could not be formed in solutions of metallic salts from which a metal can be deposited by electrolysis. It cannot be formed in strong acids having a great affinity for lead.

With ammonium oxalate and a positive electrode of platinum, there was formed on the platinum wire what appeared to be a deposit of lead peroxide, although no lead was originally in the solution. In a recent experiment I failed to produce this result.

Similar experiments were made with negative electrodes of iron, zinc, cobalt, nickel, manganese, magnesium, aluminium, copper, cadmium, silver, gold, platinum, bismuth, arsenic, antimony and tin. Of these, arsenic alone acted in a manner somewhat similar to lead, being rapidly disintegrated as a negative electrode. The surface of the metal where the action took place was smooth, bright and rounded, apparently polished. A film of brown, solid arsenic hydride

was formed, which, instead of sinking, floated away from the electrode in straight lines on the surface of the solution. This hydride was also produced electrolytically by Sir Humphrey Davy.

With lead electrodes, in a solution of sodium phosphate, some hydrogen phosphide was produced along with the lead precipitate.

With borax and lead electrodes, the lead precipitate was formed very rapidly; and when the negative electrode was held close to the side of the glass beaker, a bright reddish-brown stratum of liquid was seen to be continually formed at the surface of the electrode. This disappeared almost instantly after moving away from the electrode, but was continually formed as long as the current was strong enough to produce the lead precipitate. The addition of acetic acid did not prevent this formation.

Sodium thiosulphate gave a deposit of sulphur at the positive pole, confirming the theory that in the thiosulphates one atom of sulphur is electro-negative, and takes the place of an atom of oxygen in the sulphates.

With sodium sulphite, sulphur dioxide was liberated at the positive plate.

Strontium nitrate, instead of giving the lead powder, gave a blue flame around the point of the lead cathode.

These results seem to indicate the possibility of obtaining, by the use of high electromotive force and high current density in electrolysis, products of an entirely different nature from those of ordinary electrolysis.

A METHOD FOR DETERMINING SULPHUR IN ROASTED SULPHIDE ORES.*

By Harry F. Keller and Philip Maas.

Numerous methods have been proposed for the estimation of sulphur in materials containing it in the form of sulphides not decomposable by hydrochloric acid. New methods, as well as modifications of older ones, are contin-

* Read at the stated meeting of the Chemical Section, held January 18, 1895.

ually devised; analysts do not seem satisfied with the existing processes, and it must be admitted that a method which is both accurate and expeditious, still remains a desideratum.

The great majority of methods now practiced consist in oxidizing—either in the dry way or wet way—the sulphur to sulphuric acid, and estimating the latter gravimetrically or by titration.

The method we are about to describe is likewise based on this principle, and is a combination of well-known reactions. What we claim for it is that it is specially adapted for the determination of the sulphur in roasted copper ores and cupriferous pyrites.

The conversion of the sulphur into an alkaline sulphate is effected by fusion with potassium hydrate and sodium peroxide, and the amount of sulphur is then ascertained in the usual manner—gravimetrically, when accuracy is the principal object—by the Wildenstein method, when rapidity is aimed at.

The details of the process are as follows: Five to six grams of caustic potash (pure by alcohol) are fused in a nickel crucible and heated until the excess of water is expelled. The size of the flame is now reduced so that the contents of the crucible just remain liquid, and ·5 grams of the finely powdered material introduced in small portions. A gram of sodium peroxide is then added while the heat is gradually increased to redness, and this is maintained for a few minutes. After cooling, the fused mass is dissolved in water, and the solution filtered with the aid of a pump. The undissolved residue is washed four or five times with hot water.

The colorless* filtrate is acidified with hydrochloric acid (8–9 c.c., sp. g. 1·2) and boiled to expel carbonic acid.

If the estimation is to be made gravimetrically, the sulphate of barium is precipitated from the boiling liquid in the usual manner. In case, however, titration is resorted to, the liquid is made alkaline with ammonia (about five c.c.,

* Before filtering the liquid is often colored purple by a small amount of ferrate of potassium; a blue color in the filtrate indicates that too much potash was used.

sp. g. ·9). A slight excess of standard barium chloride solution is added from a burette, and the excess measured with an equivalent solution of dichromate of potassium. A distinct yellow color of the liquid marks the end of the reaction. After a little practice it is generally easy to strike this point, though it will sometimes happen that the precipitate does not settle rapidly. In such doubtful cases, portions of the liquid should be filtered off. Care should also be taken that the liquid does not become too dilute. It is convenient to prepare the standard solutions of such strength that one c.c. is equivalent to ·005 grams of sulphur, *i..e.*, indicates one per cent. in a sample weighing ·5 grams.

The solution of barium chloride is prepared by dissolving 38·109 grams of the crystallized salt to a liter, while the dichromate solution should contain 23 grams of the salt per liter.

To test the accuracy of our method, a considerable number of determinations were made of the sulphur in a typical roasted copper ore from Montana.

By oxidation with nitric acid and with aqua regia the percentage of sulphur in this material had been found to be 7·095 and 7·14, respectively.

Somewhat lower results were obtained by fusion with caustic potash and potassium chlorate, a method which had been used by one of us to control the working of a lead ore roasting furnace. The figures varied from 6·78 per cent. to 6·92 per cent.

Our first attempts to oxidize the ore by means of sodium peroxide were not successful. By using 10 grams of potash and 3–5 grams of peroxide, figures much lower than those before given resulted.

The oxidation was evidently incomplete. When bromine water was added to the solution of the fused mass, 6·82 per cent. of sulphur was obtained.

To our surprise a higher percentage was also found when less of the peroxide was employed. Thus with 10 grams of potash and 1 gram of peroxide the determinations averaged 6·8 per cent.

The large excess of alkali employed in these fusions in-

variably caused the solution of some copper, which renders titration impossible. Our next step, therefore, was to reduce the amount of potash.

When 5 grams of hydrate and 1 gram of peroxide were taken, the filtered solution of the fused mass was entirely free from the blue tint produced by the copper, and it is seen from the following figures that the oxidation of the sulphur was complete:

(1)	6·71	per cent.	S.
(2)	6·82	"	"
(3)	6·79	"	"
Average	6·77	"	"

Volumetric estimations gave the following results:

(1)	6·74	per cent.	S.
(2)	6·86	"	"
(3)	6·89	"	"
(4)	7·14	"	"
(5)	6·97	"	"
Average	6·92	"	"

Another series of determinations, in which a preparation of potash marked *puriss pro analys.** was used, yielded:

(1)	6·70	per cent.	S.
(2)	7·09	"	"
(3)	6·71	"	"
(4)	6·85	"	"
(5)	6·79	"	"
(6)	7·00	"	"
Average	6·85	"	"

A final series in which the directions given in this paper were strictly adhered to, resulted as follows:

(1)	6·90	per cent.	S.
(2)	6·75	"	"
(3)	7·15	"	"
(4)	7·05	"	"
(5)	7·05	"	"
(6)	7·10	"	"
(7)	7·14	"	"
Average	7·05	"	"

The time required for the volumetric assay does not exceed thirty minutes.

*A correction of ·35 per cent. was necessary in this case, the potash being less free from sulphur than that labelled "pure by alcohol."

THE ATOMIC WEIGHT OF TUNGSTEN.*

BY EDGAR F. SMITH AND ENRIC D. DESI.

When we examine Clarke's Recalculations of the Atomic Weights, or Becker's Atomic Weight Determinations, we will find various figures representing the atomic mass of tungsten, which differ greatly from each other.

The method pursued by most of the experimenters was the reduction of tungstic acid and weighing of the reduced metallic tungsten; some oxidized the metal to tungstic acid, and Bernouilli also reduced the trioxide of tungsten and calculated the atomic weight from the amount of water formed.

The cause of these great differences is due not so much to the methods employed as to the impurities contained in the material used for the experiments. All have recognized this, and their principal aim was to obtain a chemically pure tungstic acid. It is comparatively easy to rid the substance from iron, manganese, aluminum, etc. But some difficulty is encountered in removing the last traces of silicic acid, and in separating molybdenum, which was not eliminated in most determinations. The analogy of the compounds of these two metals makes their separation more difficult, and the importance of the influence of the presence of molybdic acid (MoO_3) upon the results of the atomic weight determination of tungsten was recognized by Schneider (*Journal für praktische Chemie*, **50**). He took the greatest pains in preparing a pure material, and removed the molybdic acid by strong ignition. Later investigators, however, have shown that it is not possible to completely separate tungsten from molybdenum by mere ignition.

Waddell more recently (*American Chemical Journal*, **8**, 280), after considerable and careful work, obtained probably purer material than previous investigators. He found many difficulties in separating molybdenum from tungsten, and con-

* Read before the Chemical Section, January 18, 1895.

sidered Rose's method of separation as the most convenient; but Traube (*Jahrbuch für Mineralogie*, etc. *Beilageband, VII.*, p. 232), and more recently Friedheim and Meyer (*Zeitschrift für anorganische Chemie*, **1**, 76), have shown that by Rose's method the elimination of molybdenum is not complete.

It is safe to admit that all former investigators had a tungstic acid contaminated with more or less molybdic acid, which tended to lower the atomic weight of tungsten, and the proof of it is the latest work on this subject by Pennington and Smith (*Proc. Amer. Philos. Soc.*, **33**, 332), who obtained a value (184·90), that differs quite appreciably from that usually accepted as representing the atomic mass of the element under consideration.

We have undertaken, in this present investigation, to determine the atomic weight of tungsten from the quantity of water formed by the reduction of tungsten trioxide. Bernouilli (*Poggendorf's Annalen*, **111**, 599) attempted to determine this constant in the same way, but the value which he obtained (186) we must consider as too high.

The greatest care was taken to obtain a really chemically pure tungstic acid, for the purpose of ascertaining whether the elimination of the last traces of molybdenum would be likely to produce a rise in the atomic mass.

We obtained our tungstic trioxide by digesting the finely-powdered mineral wolframite from Zinnwald (Bohemia), in aqua regia, for several days; the trioxide thus obtained was boiled in a porcelain dish for five days in aqua regia, decanting from time to time the exhausted acid, washing the yellow oxide thoroughly with water. This operation was continued until the acid and washings showed complete absence of iron. The well-washed trioxide was then brought in a porcelain dish, covered with water, and ammonia-gas conducted into the liquid until saturated, dissolving the tungstic acid to ammonium metatungstate [$W_4O_{13}(NH_4)_2 + 8H_2O$.] Several days were required for this operation, and only a little greenish residue remained undissolved, containing traces of iron and probably columbic acid. The clear ammoniacal solution, after filtration, was concentrated in a porcelain dish almost to the point of crystallization. During

this operation it was necessary to filter several times, an amorphous brown precipitate being formed, as well as a gelatinous one, probably traces of silica. The concentrated solution was left standing to crystallize out the metatungstate of ammonium. The white crystalline needles were thoroughly washed with water, dried and ignited in a porcelain crucible to tungstic acid, excluding the entrance of dust by a large, suspended porcelain cover, admitting the air freely. This tungsten trioxide was twice re-crystallized and ignited and finally digested with yellow ammonium sulphide, excluding the air as much as possible, heating gently until the solution had a reddish-brown color. A little black residue was filtered off and tungsten trisulphide (WS_3) was precipitated from the clear solution of ammonium sulphotungstate [$WS_4(NH_4)_2$], by additions of small quantities of pure hydrochloric acid. After washing the precipitate by decantation and on the filter, it was dried and ignited in an open porcelain crucible to tungstic acid. After boiling this tungstic acid for two days in aqua regia, frequently renewing the acid and washing thoroughly with water, the trioxide was dissolved once more in yellow ammonium sulphide, no residue whatever being left behind. This solution was treated as above and the resulting tungstic sulphide ignited to the trioxide.

So far, we were perfectly sure that we had no iron, manganese, aluminum, silica, etc., contaminating our tungstic acid.

Now one more element remained to be separated from tungsten, and this is molybdenum. The presence of molybdenum was proved by converting a small quantity of the purified trioxide into the ammonium salt, and applying the sulphocyanide test, Braun (*Zeitschrift für analytische Chemie*, **2**, 36), which showed plainly the presence of this element. This demonstrated that the many previous operations of purification did not eliminate molybdenum, and strengthens our opinion that the tungstic trioxide used in all former investigations, except that of Pennington and Smith (*loc. cit*), was contaminated with molybdenum. To separate these two elements we had recourse to the vola-

tility of molybdenum oxychloride (MoO_3 2HCl) Debray (*Comptes Rendus*, **46**, 1098, 1850) (*Liebig's Annalen*, **108**, 250).

The experiments of Pechard (*Comptes Rendus*, **114**, 173, and *Zeitschrift für anorg. Chemie*, **1**, 262), and those more recently made by Smith and Oberholtzer (*Jour. Amer. Chem. Soc.*, **15**, 18, and *Zeitschr. für anorg. Chemie*, **4**, 236), and by Smith and Maas (*Jour. Amer. Chem. Soc.*, **15**, 397, and *Zeitschr. für anorg. Chemie*, **5**, 280), prove beyond doubt the quantitative separation of molybdenum from tungsten by heating and passing dry hydrochloric acid gas over the mixture, the following reaction taking place:

$$MoO_3 + 2HCl = MoO_3\ 2HCl.$$

Small portions of the purified tungstic acid were placed in porcelain boats and exposed to the action of pure hydrochloric acid gas, prepared from salt and pure sulphuric acid. The gas escaping from the generating flask passed through a bottle with sulphuric acid and a tower filled with calcium chloride, and then entered the combustion tube, where it came in contact with the tungsten trioxide. A gentle heat was applied and gradually increased to about 200° C., until the white volatile sublimate of molybdenum oxychloride was no longer observed. The residue in the boat always showed some traces of reduction, so that it was re-oxidized in open porcelain crucibles. To determine complete absence of molybdenum small portions of it were subjected to the sulphocyanide test; no trace of the molybdic reaction was observed.

Only now we considered that we had a chemically pure tungstic acid, and proceeded to the actual determination of the atomic weight. This was done by conducting a current of pure and dry hydrogen over a carefully-weighed quantity of tungstic acid, collecting the water formed in a U-tube filled with freshly calcined calcium chloride.

The hydrogen used by us in the reductions was prepared from pure sulphuric acid and the purest obtainable zinc. To purify the gas it was conducted through a series of bottles containing potassium permanganate, an alkaline solution of

lead nitrate, silver nitrate, sulphuric acid, caustic potash, calcium chloride, and finally through a nine-inches-long glass tube, filled with bright, polished iron wire, the latter being gently heated. After this, the gas was admitted to the tube, where it came in contact with the ignited tungstic acid contained in a platinum boat. The water produced in the reduction was collected in a weighed, glass-stoppered U-tube, filled with anhydrous calcium chloride. A similar tube was attached to this, to prevent absorption of moisture from the surrounding atmosphere. Before beginning the reduction, the tube was dried thoroughly, until constant weight of the U-tube was obtained.

The reduction of tungstic acid is not very easy, requiring a very high temperature and long time; in our experiments we ignited for about eight hours. After displacing the hydrogen in the U-tube, it was hung in the balance-case for half an hour, and then weighed; a second weighing was made after twenty minutes, but no difference was observed. The balance and the weights were perfectly adjusted, and all weighings reduced to the vacuum standard, and in the calculations, oxygen was taken as 16 and hydrogen as 1·008 (Clarke).

The results of six experiments were as follows:

	Weight of Tungstic Acid in grams.	*Weight of Water in grams.*	*Atomic Mass of Tungsten.*
(1)	0·983024	0·22834	184·683
(2)	0·998424	0·23189	184·709
(3)	1·008074	0·23409	184·749
(4)	0·911974	0·21184	184·678
(5)	0·997974	0·23179	184·704
(6)	1·007024	0·23389	184·706
Mean,			184·704
Maximum,			184·749
Minimum,			184·678
Difference,			·071

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THE REDUCTION OF ALUMINA CONSIDERED FROM A THERMO-CHEMICAL STANDPOINT.*

BY JOSEPH W. RICHARDS, A.C., PH.D.

The writer is a firm believer in the usefulness of thermo-chemical data as a guide in chemical experiment. However, the deductions drawn from these data are often incorrect, because all the conditions have not been taken into account. Berthelot has postulated the "law of maximum work," which affirms that every chemical reaction takes place with the maximum production of heat possible by the combination of the reacting substances. This law, however, is too limited; it leaves out of consideration altogether the disturbing effect of the relative masses of the substances, their physical condition and the physical condition of the products. For instance, an excess of a reducing agent is often necessary to reduce an oxide, producing or causing to take place a highly endothermic reaction. Again, if one of the possible products of a reaction would be in such a physical condition as to be quickly and completely removed from the sphere of the reacting bodies, its formation will be greatly accelerated. If two solutions are mixed and one of the possible products of their reaction is insoluble in the solution, this fact will determine the formation of that substance, even though the reaction is an endothermic one. The heat deficit will simply be made up by an abstraction of heat from the solution; it will be cooled. Similarly, if two solids or liquids, or a solid and a liquid, are brought into intimate contact, and the possible result of their reaction should be a gas, the reaction will tend to take place, even if endothermic, because the gas escapes from the field of reaction as soon as produced, and so the inverse reaction is prevented. In such a case, putting pressure on the substances would hinder the formation of gas and retard the

* Read before the Chemical Section, February 19, 1895.

reaction; removing the pressure would facilitate the reaction. It has been proved, experimentally, that mercuric oxide and carbon react at a lower temperature when warmed in a vacuum than when at ordinary pressure.

Another important point is, that there is, under a given pressure, a critical point of temperature at which reactions first take place, the explanation of which is that the particles of the original substances are themselves bound together by chemical affinity, and that the molecular vibration corresponding to a certain temperature is necessary before the new affinities tending to produce the reaction can overcome the original affinities of the primary substances. At 555° C. the atoms of oxygen and hydrogen, in the molecules of their respective gases, are vibrating to such distances from their mutual centre of attraction, that the new affinity of the unlike atoms for each other is able to disrupt the original molecules, and combination occurs. Similarly, carbonic oxide can break up the oxygen molecule only at 655° C. These remarks apply to the free gases at ordinary pressure. Under other conditions, the oxidation can go on at different temperatures.

If the substances are brought to the critical temperature at which they react, and the reaction at that temperature is exothermic, then the exchange will take place and proceed of itself until complete. If the reaction is endothermic, the first reacting portions absorb heat from the rest and lower the temperature below the critical point, thus putting a stop to the reaction, the exchange starts again only when the temperature is kept up to the critical point by the liberal supply of heat from without. This is the *modus operandi* of the reduction of many strong oxides.

The heat of formation of a molecular weight of alumina (102 parts) was determined by Baille and Féry, by oxidizing aluminium amalgam. The reaction is

$$Al^2Hg^3 + 3O = Al^2O^3 + 3Hg = + 392{,}600 \text{ calories.}$$

This is evidently the heat of oxidation of liquid aluminium to solid alumina, *minus* the heat of formation of Al^2Hg^3. This latter quantity is unknown, but is probably quite

small. These investigators determined the heat of hydration of alumina; thus

$$Al^2O^3 + 3H^2O = 2Al(OH)^3 + 3{,}000 \text{ calories.}$$

Berthelot, long previously, had found the heat of formation of hydrated alumina to be 391,600 calories. This would give 388,600 for anhydrous alumina, but this figure is based on the oxidation of *solid* aluminium. To compare it with Baille and Féry's figures, we must *add* to it the latent heat of aluminium at 0° C., which is calculated as follows:

	Calories.
Latent heat of 1 kilo aluminium at the melting point	100·0
Heat given out by 1 kilo of molten aluminium in falling from 625° to 0° = 625 × 0·308 (sp. heat molten aluminium), determined by Pionchon . . . . . *Cal.*	192·5
Heat given out by 1 kilo of solid aluminium through the same range (writer's experiments)	158·3
Decrease in the latent heat	34·2
Latent heat of 1 kilo at 0° C.	65·8
The latent heat of 54 kilos (Al^2) is, therefore, ...	3550·0

Adding this to Berthelot's corrected value for anhydrous alumina from solid aluminium, the sum is 392,150 calories. This agrees so closely with Baille and Féry's figures that the latter are accepted as being very near the truth.

Concerning the reduction of this compound to metallic aluminium, two ways are possible—the direct and the indirect. By the first I mean the use of an agent which is powerful enough to reduce it to metal at a single step; by the indirect is meant, first, reducing alumina to a more tractable aluminium compound, and then reducing the latter. Leaving electricity entirely out of consideration, there are but very few reducing agents which can decompose alumina directly, and they only at very high temperatures. Sodium does not act on it at any temperature, since sodium oxide is a far weaker compound than alumina.

$$3Na^2 + 3O = 3Na^2O + 299{,}280 \text{ calories.}$$

If the alumina, however, is converted into an oxygen-free aluminium salt, its affinities are then much weaker, while the reducing power of sodium is relatively much greater.

Chlorine and carbon together decompose alumina,

$$Al^2O^3 + C + 6Cl = 2AlCl^3 + 3CO$$

Heat absorbed:

Decomposing alumina	392,600

Heat liberated:

Aluminium chloride	325,510	
Carbonic oxide	88,200	
		413,710
Excess of heat		21,110

This reaction proceeds easily at a bright red heat; in fact, we not only have an exothermic reaction, but the products also are all gaseous, and as soon as the critical temperature at which the reaction begins is reached, the operation proceeds rapidly and completely.

The aluminium chloride is easily reduced by sodium, potassium, lithium and magnesium, perhaps to a slight degree by manganese and zinc, which have about an equal affinity for chlorine. No other substances, organic or inorganic, besides these few rare alkaline and alkaline-earth metals, have a heat of combination with chlorine sufficient to decompose aluminium chloride.

Bromine and iodine vapors do not act like chlorine, and the reason is seen in casting up the thermal data. The difference between the heat of formation of alumina and three molecules of carbonic oxide is 392,600 — 88,200 = 304,400 calories. Against this, chlorine formed aluminium chloride and gave 325,510 calories, making the reaction exothermic by 21,110 calories. Bromine, however, in forming the bromide, gives only 243,550 calories, leaving a deficit of 60,850 calories, while iodine gives only 144,310, leaving a deficit of 160,190 calories. The only known way of making these compounds is directly from aluminium itself.

Sulphur, also, is unable either alone, or with the assistance of carbon, to split up alumina. The heat of formation of aluminium sulphide being 127,950 (from liquid aluminium), the enormous deficit of 304,400 — 127,950 = 176,450 calories, makes the reaction impracticable. However, when carbon bisulphide vapor is passed over white-hot alumina, alu-

minium sulphide is formed. It would appear at first sight as if the compound of carbon and sulphur would be less likely to produce the reaction than those elements uncombined; but the secret of this paradox is disclosed when we note that carbon bisulphide is one of the few endothermic compounds, absorbing 29,000 calories in its formation, and giving out just that amount in its decomposition. This helps to reduce the deficit by just so much. Further, carbonic oxide is not formed, but carbonyl sulphide, which has a heat of formation 4,700 calories higher for each atom of oxygen taken up. Casting up the thermal data, we have

$$Al^2O^3 + 3CS^2 = Al^2S^3 + 3COS.$$

Heat absorbed:

	Calories.
Decomposing alumina	392,600

Heat evolved:

Formation of aluminium sulphide	127,950	
" " carbonyl sulphide	102,300	
Decomposition of carbon bisulphide	87,000	
		317,250
Heat deficit		75,350

This is still a large deficiency, but the critical temperature for the reaction is a white heat, and, if the supply of carbon bisulphide is abundant and the heating is kept up energetically, the reaction is practicable.

As for reducing this sulphide to metal, thermal data show us that only the alkaline and alkaline-earth metals can accomplish it easily, while manganese, zinc, tin, iron and copper can do it to a small extent when used in large excess, making use of the influence of mass to bring about the endothermic reaction. This compound recommends itself more particularly for electrolytic decomposition. When mixed with an alkaline sulphide it forms an easily fusible double sulphide, which theoretically requires less than one volt to decompose it.

Alumina is easily converted into its fluoride, which, however, can only be decomposed chemically by the alkaline or

alkaline-earth metals. Even fluorine alone acts energetically on it, raising it to incandescence.

The reaction

$$Al^2O^3 + 6F = 2AlF^3 + 3O$$

sets free 555,550 — 392,600 = 162,950 calories, which accounts for the phenomena observed.

Even hydrofluoric acid gas can be used for the reaction, the splitting up of six molecules of gaseous hydrofluoric acid requiring, at 0° C., 222,600 calories, against which we have the formation of three molecules of water, 174,300 calories, leaving for the reaction a net excess of

$$Al^2O^3 + 6HF = 2AlF^3 + 3H^2O + 114{,}650 \text{ calories.}$$

A reaction similar to this is impracticable with hydrochloric acid gas, and we find that it would be endothermic to the extent of about 30,000 calories.

DIRECT REDUCTION.

Minet has measured carefully the voltage required to decompose alumina dissolved in a fluoride bath, using a carbon anode, at which carbonic oxide is formed. As one volt represents a thermal value of 23,000 calories for each equivalent of oxygen liberated, it would represent 23,000 × 6 = 138,000 calories for each molecule of alumina split up. The number of calories represents, therefore, the thermal value of the following reaction:

$$Al^2O^3 + 3C = Al^2 + 3CO$$

at the temperatures given. Minet's best experiments gave:

Temperature.	*Voltage.*	*Calorific Equivalent* (30.)
900°	2·40	331,000
1100°	2·17	299,460

If we can add to these numbers the heat evolved by the reaction 3C + 3O = 3CO, at these temperatures, we shall obtain the value of the reaction $Al^2 + O^3$, or the heat of oxidation of liquid aluminium to liquid alumina. This calculation is made as follows:

$$C + O = CO + 29{,}400 \text{ calories at } 0° \text{ (Berthelot).}$$

Specific heat of carbon ($t > 900°$) . . . . . $0.53 \times \frac{134.6}{t}$ (*a*)
(Pionchon.)

Specific heat of oxygen . . . . . $0.2114 + 0.00001875t$ (*b*)
(LeChatelier and Mallard.)

Specific heat of carbonic oxide . . . . . $0.245 + 0.0006t$ (*c*)
(Regnault.)

Therefore,

$$C + O \left(\begin{smallmatrix}\text{at } t^\circ \\ t > 900^\circ\end{smallmatrix}\right) = 29{,}400 + (12a + 16b - 28c)t.$$
$$= 27{,}785 + 2.8824t - 0.0003t^2.$$

Substituting, we have

At 900°, $C + O = 30{,}136$ $\quad 3(C + O) = 99{,}408$
At 1100°, $C + O = 30{,}592$ $\quad 3(C + O) = 91{,}776$

Adding these to the values of the reaction given by Minet's experiments, we have

At 900° $Al^2 + O^3 = 331{,}000 + 90{,}408 = 421{,}408$ cal.
At 1100° $Al^2 + O^3 = 299{,}460 + 91{,}776 = 391{,}236$ cal.

Now, we know that at 0°, $Al^2 + O^3 = 391{,}600$ calories, the only difference between this and the figures just derived being that the latter is calculated for *solid* alumina. For liquid alumina, we should have to subtract from it the latent heat of fusion of alumina. This is not known, but if we estimate it at forty-three calories per kilo (from analogy with other oxides), we may subtract $43 \times 102 = 4{,}400$ calories. We then have the heat of formation of liquid alumina from liquid aluminium, as follows;

	Calories.
0°	387,200
900°	421,408
1100°	391,236

It will be noticed that the value has reached a maximum between 0° and 900°, and is rapidly decreasing; in other words, above 1,000° alumina rapidly becomes easier to decompose. A curve passing through the above values would be of the following form:

$$Q = 387{,}200 + 192.6t - 0.1716t^2.$$

The question now is: "At what temperature would the heat of oxidation of our reducing agents equal the heat of formation of alumina? We may fairly assume that if that

point is above the critical point for the reaction, reduction will there begin.

Carbon.—The formula for the heat of oxidation of carbon to carbonic oxide has already been deduced. We therefore have

$$Al^2 + O^3 = 387{,}200 + 192{\cdot}6t - 0{\cdot}1716t^2$$
$$3(C + O) = 83{,}355 + 8{\cdot}6472t - 0{\cdot}0009t^2$$

When these two expressions become equal to each other

$$t = \underline{\underline{1980^\circ}}$$

If liquid carbon is the reducing agent, its efficacy is about 21,000 calories greater than solid carbon, and

$$t = \underline{\underline{1940^\circ}}$$

As verifying these calculations, I may refer to the fact that liquid alumina is, beyond a doubt, reduced by carbon in electric furnaces, because the output of aluminium is greater than the number of ampères passing through the furnace could theoretically produce, and, also, because decomposition can be produced by a rapidly-alternating current, where electrolysis is out of question. The temperature in such furnaces is probably about 3,000°. Again, in a Pennsylvania iron blast furnace, in which the temperature is almost certainly not over 2,000°, as much as one per cent. of aluminium has been reduced into the iron. The liquid carbon in the iron in the crucible is here the reducing agent, reducing aluminium from a slag carrying as high as twenty-five per cent. of alumina.

It thus appears that both calculation and practice unite in showing that carbon begins to reduce alumina in the neighborhood of 2,000° C.

Hydrogen.—

$$H^2 + O = 69{,}000 \text{ calories (to liquid } H^2O \text{ at } 0^\circ)$$
$$= 58{,}100 \quad \text{“} \quad \text{(to vapor of water at } 0^\circ)$$
$$\text{Specific heat of hydrogen} = 3{\cdot}3820 + 0{\cdot}0003t \qquad (a)$$
$$\text{“} \quad \text{“} \quad \text{“ oxygen} = 0{\cdot}2214 + 0{\cdot}00001875t \qquad (b)$$
$$\text{“} \quad \text{“} \quad \text{“ water vapor} = 0{\cdot}4208 + 0{\cdot}000182t \qquad (c)$$
$$H^2 + O \text{ (at } t^\circ) = 58{,}100 + (2a + 16b - 18c)t$$
$$= 58{,}100 + 5{\cdot}9544t - {\cdot}001712t^2$$

We therefore have

$$Al^2 + O^3 = 387{,}200 + 192{\cdot}6t - 0{\cdot}1716t^2$$
$$3(H^2 + O) = 174{,}300 + 17{\cdot}863t - 0{\cdot}0051t^2$$

When these two expressions become equal to each other,

$$t = \overline{\overline{1770^\circ}}$$

This is just about the melting point of platinum, and may appear lower than can possibly be the fact; nevertheless, Mr. H. Warren, in England, has recently succeeded in reducing alumina to aluminium in a current of hydrogen gas, the alumina being inside a lime tube heated on the outside by the oxyhydrogen flame. It is hardly possible that the temperature inside the tube could have exceeded 2,000°; yet complete reduction to metallic globules was obtained.

This second confirmation of the calculations by experiment induces me to add, in conclusion, the following observations:

Acetylene gas, C^2H^2, has a negative heat of formation of 51,500 calories. It is, therefore, just by that much a more powerful reducing agent than C^2 and H^2 alone. The equation is:

$$Al^2O^3 + C^2H^2 = Al^2 + 2CO + H^2O$$

The thermal equations are:

$$Al^2 + O^3 = 387{,}200 + 196{\cdot}2t - 0{\cdot}1716t^2 \qquad (a)$$
$$2(C + O) = 55{,}570 + 5{\cdot}7648t - 0{\cdot}0005t^2 \qquad (b)$$
$$H^2 + O = 58{,}100 + 6{\cdot}7640t - 0{\cdot}0006t^2 \qquad (c)$$
$$C^2 - H^2 = 51{,}500 \qquad (d)$$

making $b + c + d = a$

$$t = \overline{\overline{1870^\circ}}$$

I am inclined to think that this highly endothermic compound would reduce alumina at an even lower temperature than this, because we have not only the benefit of its great heat of decomposition, but we also have, at the moment when it decomposes, the carbon and hydrogen atoms *in statu nascendi*, and we thus have all the advantages of a *nascent* reducing agent. I need not, to an audience of chem

ists, expatiate on the greater chemical activity of a nascent reducing agent.

The recent developments in the manufacture of calcium carbide and acetylene open up a possibility in the way of reducing alumina which may bear fruit. Allow me, at least, to claim for thermo-chemistry, rightly understood, that it is a most helpful guide to intelligent experiment.

LEHIGH UNIVERSITY, Bethlehem, Pa., February 19, 1895.

THE ACTION OF MAGNESIUM UPON THE VAPORS OF THE ALCOHOLS AND A NEW METHOD OF PREPARING ALLYLENE.*

BY EDWARD H. KEISER AND MARY B. BREED.

Under certain conditions magnesium is one of the most active elements. At high temperatures, as is well known, it has the power of reducing many of the most stable oxides, and in the absence of oxygen it can combine with nitrogen and form a nitride. That magnesium can also unite with carbon and form derivatives of the hydrocarbons will appear from the experiments described in this paper. An exhaustive study of the action of magnesium upon the oxides and hydroxides of the elements has been made by Winkler (*Ber. d. deutsch. Chem. Ges.* **23,** 120, 772, 2642), and Seubert and Schmidt (*Liebig's Annalen,* **267,** 218) have studied its effects upon the chlorides of the elements. So far as we know, no one has hitherto examined systematically the action of magnesium upon organic compounds containing oxygen. Preliminary experiments showed us that when magnesium is heated with organic oxygen compounds, such as alcohols, acids, ketones, etc., a reaction, accompanied by an incandescence of the metal, takes place at more or less elevated temperatures. Thus far we have studied in detail the

* Read at the stated meeting of the Chemical Section of the Franklin Institute, held December 18, 1894.

action of the metal upon several alcohols, and, as one of the results, have found a ready method of obtaining the unsaturated hydrocarbon, allylene, C_3H_4.

The experiments were conducted as follows: The magnesium, in the form of filings, was placed in a porcelain or iron boat, and heated in a combustion tube through which the vapor of the alcohol was passed. Before raising the temperature of the magnesium, the air in the apparatus was expelled by the alcohol vapor. At a low-red heat the magnesium begins to glow at one end of the boat, and usually, after a few moments, it becomes red hot throughout its entire mass. The boat and its contents are then allowed to cool down in the alcohol vapor. During the time that the magnesium is glowing, large volumes of gas are evolved from the tube. These gases were in each case collected in a gasometer, and subsequently analyzed.

The first alcohol examined was methyl alcohol. The magnesium, a at low-red heat, acts energetically upon it. After cooling, the residue in the boat has the appearance of a dark, black, coherent mass. When brought into water, this black residue slowly gives off a gas. If now a drop or two of a solution of ammonium chloride be added, a moderately rapid current of gas is given off. This gas has an odor like that of acetylene, but when it is conducted through an ammoniacal solution of cuprous chloride, the greenish-yellow precipitate of cuprous allylide is formed. In an ammoniacal solution of silver nitrate, a white crystalline precipitate of silver allylide is obtained. Both these precipitates, when they are filtered off, washed and dried, explode if they are heated up to about 150°. When treated with dilute nitric or hydrochloric acids, they dissolve with an evolution of allylene. The silver precipitate can be obtained in pure condition more readily than the copper compound. An analysis of the former gave the following result:

I. ·1292 grams gave ·1270 grams AgCl = 73·97 per cent. Ag.
Calculated for C_3H_3Ag, 73·45 " "

The gas which was given off during the time that the

magnesium in the porcelain boat was glowing in the methyl alcohol vapor, gave, on analysis, the following results:

CO_2	·8
CO	·6
CH_4	19·7
H	78·9
	100·0

The action of zinc dust upon the vapor of methyl alcohol has been examined by W. Jahn (*Monatshefte*, 1880, **1**, 378 and 675), who found that the chief products were hydrogen and carbon monoxide. As a by-product, a small quantity of marsh gas was obtained. It is evident, from the above analysis, that the action of the magnesium is essentially different, the carbon monoxide being practically absent in the products obtained when this metal acts upon the methyl alcohol. We have found that another metal, namely iron, decomposes the methyl alcohol vapor in the same way that zinc does. Thus, when the methyl alcohol vapor was passed through a tube containing iron, as, for example, a boat made of thin iron sheet, the alcohol was decomposed into carbon monoxide and hydrogen. An analysis of the gas thus obtained gave the following results:

CO_2	3·8
CO	26·8
CH_4	1·6
H	67·4
	99·6

In short, when methyl alcohol is passed over heated metals, such as iron or zinc, it is resolved into hydrogen and carbon monoxide; if it be passed over heated magnesium, the chief products are hydrogen and marsh gas.

The next alcohol examined was ethyl alcohol. The action in this case was similar to that described in the case of methyl alcohol. The residue remaining in the boat was treated with water and a few drops of ammonium chloride solution, and the gas that was given off was conducted through a series of bottles containing an ammoniacal solu-

tion of silver nitrate. The white crystalline precipitate, on analysis, gave the following percentage of silver:

I. ·1163 grams gave ·11365 grams AgCl = 73·53 per cent. Ag.
II. ·0979 " " ·09615 " " = 73·89 " "
Calculated for C_3H_3Ag, 73·45 " "

In this case also, allylene is given off when the magnesium residue is decomposed by water. The gases formed during the action have the following composition:

CO_2	0·0
CO	·4
C_2H_2	10·0
C_2H_4	4·0
CH_4	11·1
H	72·9
	98·4

The chief constituent again is hydrogen. Carbon monoxide is practically absent, as we should expect, knowing that this gas is reduced by magnesium. Acetylene and marsh gas are present in about equal quantities. Jahn found that zinc dust, at low temperatures, decomposes ethyl alcohol smoothly into ethylene and water, the latter being reduced to hydrogen by the zinc. At higher temperatures he obtained hydrogen, marsh gas and carbon monoxide, and a trace of acetylene. We have found that iron decomposes ethyl alcohol in very much the same way that zinc does at elevated temperatures. The gas obtained by passing ethyl alcohol over heated iron had the following composition:

	CO_2	·5
	CO	18·0
Unsaturated Hydrocarbons	$C_2H_2 + C_2H_4$	4·0
	CH_4	13·0
	H	63·8
		99·3

Propyl alcohol was examined in the same way. In this case the black magnesium residue is decomposed by water at the ordinary temperature, and the quantity of silver precipitate is very much greater than in the preceding cases. So readily is allylene obtained from propyl alcohol and magnesium by this method, that for the purpose of

preparing the gas for experiments on the lecture table it is much to be preferred to the ordinary method of decomposing propylene bromide with alcoholic potash. Analysis of the pure white silver allylide thrown down in the second wash-bottle from the generating flask gave, on analysis, 73·39 per cent. of silver.

·15605 grams gave ·1522 grams AgCl = 73·39 per cent. Ag.
Calculated for C_3H_3Ag = 73·45 " "

The precipitate in the first wash-bottle was not so pure; it evidently contained some silver acetylide. On analysis, ·20095 grams gave ·19985 grams AgCl, or 74·83 per cent. Silver acetylide contains a higher percentage, namely, 89·99 per cent. of silver.

An analysis of the gases formed when the magnesium acts upon propyl alcohol, showed that in general the action is similar to that which took place in the experiments with ethyl alcohol. The analysis gave these figures:

CO_2	0·0
CO	3·5
Unsaturated hydrocarbons	17·8
Saturated "	19 9
H	57·8
	99·0

The chief products of the decomposition of propyl alcohol, under the action of magnesium, are hydrogen and saturated and unsaturated hydrocarbons, the latter being present in nearly equal volumes. The same alcohol is decomposed by heated iron in a different way, the analysis of the gas having given the following values:

CO_2	·6
CO	16·4
Unsaturated hydrocarbons	16·7
Saturated "	23·6
Hydrogen	42·7
	100·0

With zinc dust, Jahn found that, at low temperatures, propylene and hydrogen are the chief products.

The other alcohols that have been examined are allyl, isobutyl and amyl alcohols. The first of these,

namely, allyl alcohol, is even better than normal propyl alcohol for the preparation of allylene. An abundant precipitate of silver allylide is obtained, and an analysis showed that it was free from silver acetylide.

I. ·17185 grams gave ·16735 grams AgCl = 73·27 per cent. Ag.
Calculated for C_3H_3Ag = 73·45 " "

In this case the precipitate obtained in the first wash-bottle gave, on analysis, a result which showed that it contained no silver acetylide.

·16705 grams gave ·1620 grams AgCl = 72·97 per cent. Ag.
For C_3H_3Ag = 73·45 " "

The ease with which, from a few cubic centimeters of propyl, or allyl, alcohols and a few grams of magnesium powder, an appreciable quantity of allylene silver can be obtained, makes this method of preparing allylene much more convenient than the one ordinarily used.

From isobutyl alcohol and magnesium, a residue was obtained, which, on treatment with water and ammonium chloride, gave a gas which, besides hydrogen, contained acetylene and allylene, as was shown by the percentage of silver in the silver precipitate.

·18335 grams gave ·18845 grams AgCl = 77·33 per cent. Ag.

From amyl alcohol the yield of silver precipitate was not very large, but here also the unsaturated hydrocarbon was allylene.

·08585 grams gave ·08365 AgCl = 73·31 per cent. Ag.

Other alcohols and organic compounds containing oxygen will be investigated in a similar way.

NOTES AND COMMENTS.*

ISOLATION OF HYDROGEN PEROXIDE.

Anhydrous hydrogen peroxide has at last been isolated by Dr. Wolffenstein in the laboratory of the Technischen Hochschule at Berlin, and the somewhat surprising fact demonstrated that this substance, which has hitherto been regarded as possessing but little stability, is capable of actual distillation with scarcely any loss under reduced pressure.

* From the Secretary's monthly reports.

In attempting to concentrate solutions of hydrogen peroxide in vacuo by the method of Talbot and Moody, and also in the open air upon the water bath, a solution as strong as sixty-six per cent. H_2O_2 was obtained, but with a loss of over seventy per cent. of the original amount of peroxide employed. Moreover, it was found that when the common commercial three per cent. solution is concentrated, the percentage of H_2O_2 may be brought up to forty-five without the loss of any considerable quantity of the peroxide by volatilization, but that as the concentration continues to rise above this limit the volatilization of the peroxide increases at a very rapid rate; for the great loss was proved to be due not to decomposition, but to actual vaporization of the substance. Evidently hydrogen peroxide is remarkably stable at the temperature of a water bath. An attempt was therefore made to actually distill it under reduced pressure. A quantity of commercial peroxide which had been further concentrated until it contained about fifty per cent. H_2O_2 was first purified from all traces of suspended impurities, and at the same time still further concentrated by extraction with ether. After evaporation of the ether the solution was found to contain seventy-three per cent. H_2O_2.

This solution was then submitted to distillation at the temperature of the water bath and under the reduced pressure of sixty-eight millimetres of mercury. The distillate was received in two fractions, boiling at 71°–81° and 81°–85° respectively. The first fraction contained forty-four per cent. H_2O_2, while the latter was found to contain no less than 90·5 per cent. Upon again fractionally distilling the latter product, a large proportion distilled at 84°–85°, and this fraction proved to be practically pure H_2O_2, containing over ninety-nine per cent. of the peroxide. The liquid thus isolated is a colorless syrup which exhibits but little inclination to wet the surface of the containing vessel. When exposed to the air it evaporates. It produces a prickly sensation when placed upon the skin, and causes the appearance of white spots, which take several hours to disappear again. As regards the much-discussed and disputed question of the reaction of hydrogen peroxide toward litmus, Dr. Wolffenstein finds that even when the pure liquid is made strongly alkaline with soda and again distilled, the distillate exhibits strong acid characters, so that the acid nature of hydrogen peroxide must be regarded as fully established. It is finally shown that the use of ether in assisting the concentration is by no means essential. Ordinary commercial three per cent. peroxide can be immediately subjected to fractional distillation under reduced pressure, and a fraction eventually isolated, consisting of the pure substance boiling at 84°–85° under a pressure of sixty-eight millimetres.—London *Nature*.

PROGRESS OF IRRIGATION.

The *Scientific American* gives the following interesting summary of the progress which is being made in the work of reclaiming, for the purposes of agriculture, the vast tracts of arid land in the far West:

The irrigated and irrigable lands of the western part of the United States are mainly included between the one-hundreth meridian and the Pacific Ocean, and comprise, according to official surveys, about 610,000,000 acres.

Within this great extent of country are nearly all possible combinations of soil and climate. In a general way, however, four great classes may be distinguished. These are desert, pasture, fire-wood and timber lands. Of these, the desert land is practically valueless, the pasture land is too arid to support vegetation and may be used only as a pasturage, and only the latter two divisions are more or less fertile. The irrigated sections are included in the desert and pasture lands. At present some 3,631,381 acres (or less than six-tenths of one per cent. of the entire region) have been provided with an artificial water supply sufficient to raise crops.

The proportion of this desert or pasture land which may, in the future, be brought under irrigation depends, of course, upon the thoroughness and ingenuity with which the water supply is utilized, but it is probable that it will be under three per cent. of the entire area. Statistics show, however, that irrigation is a profitable measure and cannot be neglected. The average cost of water for irrigation throughout this section is at the rate of $8.15 per acre. Applying these figures to the total acreage the total first cost of irrigating the lands last year was about $30,000,000, and the total value of the water right was $94,412,000, the increase of valuing being $64,800,000, or 218·84 per cent. of the investment. The estimated first cost of the irrigated lands from which crops have been obtained was $77,500,000 in 1889, and their present value, including the improvements, is $296,850,000, showing an increased value of $219,360,000, or 283·08 per cent. of the investment in the land. The average value of the crop raised was $14.89 per acre, or a total of $53,057,000. This, it must be considered, exhibits merely the cost and value of irrigation in the arid regions. The value of the unutilized water supply can scarcely be estimated.

During the past four years the Federal Government has done much to further the work of irrigation by establishing an irrigation survey and by appointing State engineers in California, Colorado and Wyoming, whose duties are practically confined to irrigation.

At present the irrigation of this region is carried on by what is called gravity irrigation.

The different systems adopted by modern engineers may be classified as perennial, periodical and storage work, by irrigation from artesian wells and from sub-surface sources. The perennial irrigation includes the supply of water from canals which receive their supply from streams which give a constant supply of water throughout the entire year.

Periodical irrigation includes the canals which have a supply only at certain seasons of the year. A more common plan, however, is the storage system. The dams for this system are generally constructed on intermittent streams for the purposing of receiving and preserving their flood waters.

The irrigation from artesian wells is practiced wholly by means of canals, which convey the water to the land directly from the wells. And the irrigation from ground-water sources is performed by tunnels under the beds of streams, which tap some water-bearing stratum, or by cuts in sloping ground, by wells to collect the ground-water and by similar contrivances.

The work of irrigation calls for much skill and scientific knowledge.

Climate, geology and topography must all be considered in the work. It is to be hoped that the skilled engineers now at work on the subject will provide an economical and efficient system for the future.

AS TO THE SIN OF PLAGIARISM: SOME REFLECTIONS, IRONICAL AND OTHERWISE.

There are occasions when the display of virtuous indignation is proper, even highly praiseworthy, and the writer can sympathize with the sentiment which induced the Western Foundrymen's Association, at one of its recent monthly meetings, to expurgate its records by withdrawing therefrom a paper which had manifestly been copied, without credit to the author, from a published book.

The history of the event to which the above remarks apply is given in sufficient detail for the present purpose, in the following extract from the proceedings of the meeting of that Association, which appeared in *The Iron Age* of February 28, 1895, viz.:

PLAGIARISM OF SISSON'S "A B C OF IRON."

The Investigating Committee, appointed by the Chair, returned and presented the following report:

"Your committee respectfully report that they have compared the paper presented by Chas. Johnson with Sisson's "A B C of Iron," and find that it is almost entirely copied from that book. We therefore recommend that the following resolution be adopted, and that the Secretary be authorized to carry out its instructions:

"*Resolved*, It having been found that the paper by Charles Johnson, read at the last meeting of this Association, should not have been presented as an original paper, the Secretary is instructed to withdraw it from the records of the Association, together with all resolutions relative thereto."

The report of the committee was adopted and ordered spread upon the records.

The reading of this somewhat severe public rebuke aroused the curiosity of the writer to examine the book with the alphabetical title; for, as imitation is said to be the sincerest form of flattery, it was reasonable to believe that what was worth the trouble—not to mention the risk—of stealing, must have some merit or value.

Here is what the examination disclosed:

Sisson's book is an octavo of ninety-nine pages, of which about fifty pages are actually credited, either by honest quotation marks or by presenting the names of authors (though in *very* subordinate type), to their legitimate sources.

With the possible exception of a chapter of three pages on "How to Reduce Cost of Mixture," concerning which Mr. Sisson is entitled to the benefit of the doubt, the remainder of the book is simply a piece of patchwork made by a bungling amateur, with the aid of scissors and paste-pot and conjunctions.

The source of much of Sisson's uncredited material is made sufficiently clear by the method of the deadly parallel column employed in the following exposition:

"PIG IRON,

"Including the Relation Between its Physical Properties and its Chemical Constituents.

"By Alex. E. Outerbridge, Jr.,

"*Journal of the Franklin Institute, March, 1888.*

"Manufacturers are beginning to realize that pig iron is not a simple substance, but is, in reality, an alloy, composed of a number of dissimilar elements; that its physical characteristics, such as strength, elasticity, etc., depend upon the percentages of these constituents, and that pure iron, like pure gold, is always the same thing physically and chemically, no matter from what source it may be obtained.

"We believe that the time is coming when pig iron will be sold on its chemical analysis, instead of on the crude methods of grading at present in vogue, and further, that, as the naturalist can accurately tell the genus of an animal from an examination of a single bone, so the analyst will tell the physical qualities of a mass of iron from an analysis of its component parts.

"The element which exerts the most vital influence upon the character of pig iron, is carbon.

"Carbon exists in pig iron in two distinct forms, and upon the relative proportion of each depends, in great measure, the character of the metal.

"Silicon stands next in importance to carbon, in respect to its effect upon the character of the metal. It exerts a controlling influence upon the chilling properties of the iron, since its tendency is to prevent the chemical combination of the carbon and iron. * * * The notion has long prevailed (like many other fallacies born of ignorance) that silicon produces 'blow-holes,' or unsound castings, but such is not the case.

"Phosphorus, as an element in pig iron, tends to render the molten metal very limpid, so that it will take an extremely fine and sharp casting from the most delicate patterns.

"THE A B C OF IRON.

"By Chas. W. Sisson.

"*Louisville, Ky., 1893.*

"Manufacturers now realize that pig iron is not a simple substance, but is, in reality, an alloy, composed (sic) of a number of elements very dissimilar; that its physical characteristics, strength, elasticity, etc., depend upon the percentages of these elements (third line of Introductory, *et seq*). * * * Pure iron, like pure gold, is always the same thing physically and chemically, no matter from what source it comes (p 44). * * *

"We feel that the time is not far distant when all iron must be sold on basis of analysis (p. 45). * * *

"There is no reason why a chemist should not tell the physical qualities of pig iron from an analysis as easily and accurately as the naturalist can tell the genus of an animal from an examination of a single bone (p. 44).

"Carbon exerts the most vital influence on pig iron of all the elements (p. 21).

"It (carbon) exists in pig iron in two distinct forms, the combined and graphitic, and upon the relative proportion of each, in a great measure, depends the character of the metal (p. 21).

"Next to carbon, silicon is the commonest and most abundant constituent of cast iron. * * * The effect of silicon is to change the combined carbon into graphitic carbon. * * * It increases the fusibility and fluidity of iron, lessens the formation of blow-holes, and reduces shrinkage (p. 25).

"Its tendency (phosphorus) is to render the metal very limpid, so that it will take an extremely fine and sharp casting from the most delicate patterns.

"The famous Berlin castings of reproductions in iron of ancient armor, and other ornamental objects, are obtained by using iron rich in phosphorus, but it possesses the disadvantage of rendering the metal brittle and unfit for many practical uses. * * * The percentage of phosphorus in pig iron may vary from a trace to one and one-half per cent.

"Sulphur is, without doubt, the most deleterious substance found in pig iron. The other elements all produce effects which may be beneficial for certain purposes, but sulphur is an enemy greatly to be dreaded, since it has a strong affinity for iron, combining with it at a low temperature. * * *

"The presence of sulphur in pig iron is due mainly to bad fuel.

"The chemistry of iron, in its connection with the manufacture of Bessemer steel, has, from the necessities of the case, been carried to a fine degree of perfection, but it is a matter of surprise that so little is known practically in the foundry and workshops in regard to the cause of these wide variations, which are a frequent source of difficulty in manipulation of the metal, and loss of time, money and labor.

"The subject is, however, beginning to attract a share of the scientific attention which has been bestowed upon the chemistry of steel, and upon which the success of that industry so largely depends.

"NOTES ON THE BLAST FURNACE.

"BY JOHN HARTMAN.

"*Journal of the Franklin Institute, August, 1892.*

'STANDARD NO. 1. PIG IRON.

"*Gray.*—A large, dark, open-grain iron, softest of all the numbers, and used exclusively in the foundry. Tensile strength, low. Elastic limit, low. Fracture, rough. Turns soft and tough.

"NO. 2. PIG IRON.

"*Gray.*—A mixed large and small dark grain, harder than No. 1 iron.

"The famous Berlin castings of reproductions in iron of ancient armor, and other ornamental objects, are obtained by using iron rich in phosphorus, but it possesses the disadvantage of rendering the metal brittle and unfit for many practical uses (p. 29). * * * The percentage of phosphorus in pig iron varies from a trace to one and one-half per cent. (p. 30).

"Sulphur is, without doubt, the most deleterious substance found in pig iron. The other elements all produce effects which may be beneficial for certain purposes, but sulphur is the enemy dreaded by all, on account of its affinity for iron combining with it at a low temperature (p. 34).

"The presence of sulphur in pig iron is due mainly to its absorption from the fuel (p. 34).

"The success of the steel industry is largely due to the scientific attention bestowed upon the chemistry of steel, and its manufacture has been carried to a fine degree of perfection. There is no reason why iron should not reach the same perfection and be sold by analysis, as steel is (p. 45).

"THE A B C OF IRON.

"BY CHAS. W. SISSON.

"*Louisville, Ky., 1893.*

"*No. 1 Foundry* is the darkest of the numbers as well as the softest, as it contains the most graphitic carbon, and is used exclusively in the foundry. In appearance the fracture is dark in color, rough, open grain; tensile strength and elastic limit, low; turns soft and tough (p. 37).

"*No. 2 Foundry* is more genera ly used with foundry than any other

and used exclusively in the foundry. Tensile strength and elastic limit higher than No. 1. Fracture, less rough than No. 1. Turns harder, less tough and more brittle than No. 1.

"No. 3. PIG IRON.

"*Gray.*—Small, gray, close grain, harder than No. 2 iron, used either in the rolling mill or foundry. Tensile strength and elastic limit higher than No. 2. Turns harder, less tough and more brittle than No. 2. * * * Graphitic carbon lower, and combined carbon higher than No. 2. * * * The strength for tension culminates in No. 3 pig iron.

"No. 4. PIG IRON.

"*Mottled.* — White background, dotted closely with small black spots of graphitic carbon, little or no grain. Used exclusively in the rolling mill. Tensile strength and elastic limit lower than No. 3. Turns with difficulty, less tough and more brittle than No. 3 * * * Graphitic carbon lower and combined carbon higher than No. 3.

"No. 5. PIG IRON.

"*White.*—Smooth, white fracture, no grain, used exclusively in the rolling mill. Tensile strength and elastic limit much lower than No. 4. Too hard to turn and more brittle than No. 4. * * * The patches are small and closer, but no grain. No graphitic carbon, all combined carbon."

grade. The grain is not so open and large as No. 1 Foundry, but the iron is harder and stronger, although less tough and more brittle (p. 37).

"*No. 3 Foundry* is used for both mill and foundry purposes. It is much stronger than Nos. 1 and 2, the grain being closer and more compact. It turns hard, is less tough and more brittle than No. 2. The strength for tension seems to reach its limit in this grade. * * * The percentages of graphitic carbon and silicon are smaller and contained carbon larger than in No. 2" (p. 38).

"*Mottled.*— * * * Mottled iron is used exclusively for puddling purposes. Turns with great difficulty, less tough and more brittle Gray Forge. Graphitic carbon and silicon lower than in Gray Forge and combined carbon higher" (p. 38).

"*White.*— * * * It has a smooth, white fracture, no grain, and is used exclusively in a (sic) rolling mill; tensile strength and elastic limit very low; too hard to turn or drill, as the carbon in this grade is about all in the combined state" (p. 39).

Other "adaptations," familiar though elusive, crop out elsewhere in this interesting production of Mr. Sisson. But enough has been shown in the comparative exhibit to make it clear, that however proper and even praiseworthy may have been the virtuous indignation of the foundrymen over the unhandsome behavior of Mr. Johnson, the emptying of the vials of their wrath on his devoted head for the crime of re-cribbing from Sisson, was not only too severe upon the unlucky subject of their displeasure, but under the circumstances, was an act which, without violating the proprieties, might even be called ridiculous.

Mr. Sisson's method of "adapting" other men's work is simplicity itself, and consists merely in judiciously sprinkling, throughout his book, portions of sentences which were continuous in the original. He leaves himself a loop-hole for escape from the charge of moral delinquency, in the event of detection, by the comprehensive statement in his introduction, that "except

where extended quotations are given no mention is made of the authority, for the reason that it often became necessary to change the language to have it simple and readily understood." (Here's richness, as Mr. Squeers would say).

It is evident that there is nothing mean about Mr. Sisson. He not only appropriates the work of others without credit, but is generous enough also to assume to improve upon it.

As an example of such improvement take the following: In speaking of silicon in his lecture, Mr. Outerbridge had said: "Its tendency is to produce an exceedingly fluid iron, retaining its heat for a long time, owing, I believe, to a fact not generally known, that the specific heat of iron rich in silicon is much higher than that of a similar grade of iron containing but little of that element." It would seem that there was too much "high science" in this for Mr. S. He accepted the "fluidity," but evidently thought the "specific heat" part of the statement needed simplification, and hit upon "fusibility" as a synonym. Accordingly, the sentence is made to read: "It increases the fusibility and fluidity of iron."

Again, Mr. Outerbridge had found as the result of some hundreds of experiments that the addition of a small quantity of ferro-manganese (one pound in 600 pounds of iron), increased *strength* forty per cent. and decreased chill. Mr. S. says (p. 32): "An increase of one per cent. manganese has increased the *hardness* forty per cent.;" and in the next sentence adds: "Mr. Keep's tests show that manganese does not increase chill."

As increased chill and increased hardness go together, irrespective of manganese, this wild shot at "simplifying" what he did not understand, if not quite a bull's-eye, is just near enough to be a "bull;" and, with other attempts of the author at simplification—not to speak of his frequent efforts to improve the accepted spelling of English—may stand as a conspicuous illustration of the fact that "a little knowledge is a dangerous thing."

W.

TESTS OF NON-CONDUCTING PIPE COVERINGS.

A series of tests have been made at the St. Louis Water Works by John A. Laird, to select the most suitable covering for pipes, boiler shells, etc., in the new pumping station at the Chain of Rocks. The report appears in the "Proceedings" of the Association of Engineering Societies. There were purchased asbestos sponge moulded sectional covering, asbestos fire-felt sectional covering and magnesia sectional covering, all for one-inch pipe. Also, asbestos sponge cement felting, asbestos cement felting, plastic magnesia and fossil meal. Tests were also made on plaster of Paris and sawdust, moulded into covering for one-inch pipe.

The different coverings were subjected to chemical examination by Mr. Wixford, chemist of the water works, with the following approximate results:

Asbestos Sponge (*Moulded*).

Plaster of Paris	95·8
Fibrous asbestos	4·2

Asbestos Fire Felt.

Asbestos	82·
Carbonaceous matter not determined	18·

Magnesia (Sectional).

Magnesia	92·2
Fibrous asbestos	7·8

Magnesia (Plastic).

Magnesium carbonate	93·
Fibrous asbestos	7·

Asbestos Cement Felting.

(Probably) powdered limestone	64·5
Plaster of Paris	3·5
Asbestos	32·

Asbestos Sponge Cement Felting.

(Probably) powdered limestone	59·
Plaster of Paris	10·
Asbestos	31·

Fossil Meal.

Insoluble silicate	80·
Carbonaceous matter, hair, paper, sawdust, etc.	12·
Soluble mineral matter	8·

On all condensation tests the gauge pressure was held at twenty-five pounds. The water was drawn off every fifteen minutes and was measured in cubic centimeters. Each test was continued for four hours. The mean results are tabulated below.

Condensation Tests.

Name of Covering.	*C.c. Condensed Per Hour.*
Magnesia (plastic)	334·
Magnesia (sectional)	335·3
Asbestos fire-felt	367·5
Asbestos sponge (moulded)	371·3
Fossil meal	376·2
Plaster of Paris and sawdust	438·
Asbestos fire-felt cement	563·7
Asbestos sponge cement	604·
Bare pipe	1085·

On the question of durability, Mr Laird states that the magnesia sectional covering which has been on pipe at Bissell's Point for four years shows no signs of deterioration; also that the asbestos sponge moulded covering which has been on pipes at Harlem Creek for less than two years is becoming soft, and the plaster of paris seems to be reduced back to the original powder, with nothing but the fibrous asbestos to hold it together. Another question is that of steam pressure. The experiments were made at the High Service Station, No. 2, and it was found convenient to have all tests made at twenty-five pounds gauge pressure. As the working pressure at Chain of Rocks will be at least 125 pounds, the relative efficiency of insulation will be slightly changed, but, in Mr. Laird's opinion, not enough to change the conclusions here arrived at.—*Iron Age.*

BOOK NOTICES.

A Laboratory Manual of Physics and Applied Electricity.—Arranged and edited by Edward L. Nichols, Professor of Physics in Cornell University. In two volumes. Vol. I, Junior Course in General Physics. By Ernest Merritt and Fredk. J. Rogers. New York and London: Macmillan & Co. 1894.

One of the best evidences of the remarkable changes in the methods of instruction in modern schools of engineering in the United States is afforded by the text-book now under consideration. The plan of the work assumes that the student has access to physical apparatus and that he shall be required to conduct, under his own supervision, the experimental work of testing and verifying the principles of the sciences on which his intended professional work is based. Nothing more unlike the methods of twenty years ago in our best schools could be imagined.

The present volume has been edited by Professor Nichols, with the aid of his assistant instructors, to supply the needs of the student in the physical praktikum, which the existing manuals on physics are found to meet only in an inadequate manner. The method pursued is to follow the statement of a proposition by an experimental demonstration bearing directly upon it, and to verify each step as the student goes along. A text-book for more advanced students, arranged on the same general lines, is presently to follow. W.

The Steam Engine and Other Heat Engines.—By J. A. Ewing, M.A , B.Sc., F.R.S., M. Inst., C.E., Professor of Mechanism and Applied Mechanics in the University of Cambridge. University Press: Macmillan & Co. $3.75.

This work, by an author of acknowledged reputation, not only in his own line—that of mechanics—but also in the allied subject of electricity, naturally excites anticipations of a favorable character. Study of its pages proves no disappointment. The book is, in some respects, quite different from any other text-book on the subject, and is written in the clear and masterly style always characteristic of Professor Ewing's work, and happily different from the confused and complicated verbiage of the majority of English technical writers.

The work is, as a whole, based on the article on "Steam Engine," written by Professor Ewing for the Encyclopædia Brittanica, but is much more complete than that article, and systematized, and in its present form is offered so as to be more useful for reference.

The aim of the author has been to collate and make evident the relation of steam-engine theory and practice. Starting out with a chapter on the early history of steam and heat engines, and tracing its gradual evolution, there follow a number of chapters devoted to the dynamic theory of steam and the application of this theory in practice. The use of diagrams is quite extensive, in particular that of the Entropy temperature diagram, as a means of exhibiting thermodynamic actions; then follows a study of the actual behavior of steam

in the cylinder, and a treatment of the subject of compound expansion. The well-known work of Dr. Emery is mentioned and quoted. The subject of valve gears and the theory of governing also receives considerable attention.

The discussion of what constitutes the best type of steam engines in different conditions, as evidenced by present-day practice, is rather slurred over, but few forms receiving any attention. In a practical work, while deprecating the tendency to profuse description too frequently indulged in by many writers, it would, nevertheless, seem as if some space, devoted to a detailed discussion of a number of characteristic types of engines, would have been valuable. Thus, for example, a consideration of the relative merits of high- and low-speed engines; the pros and cons regarding various types of compound engines; the practical advantages gained by working with high steam pressures, etc., are matters concerning which the average engineer requires fuller exposition.

The steam turbine has but a few pages given it, although many readers would have welcomed full information from so authoritative a writer, there being no question but that this form of motor is one of those things which, logically, should develop into a prime mover of considerable practical value.

The closing chapter is on air, gas and oil engines. Upon this subject, also, greater completeness would have been desirable. Engines of this type are proving themselves of rapidly increasing value, in view of the downward tendency in the price of gas and the large development of natural gas supplies. The literature of the subject, as is well known, is exceedingly incomplete and old-fashioned.

On the whole, the book is a valuable one and offers much that is suggestive, while the exposition, as previously mentioned, is clear and to the point.

E. G. W.

Franklin Institute.

[*Proceedings of the stated meeting, held Wednesday, March 20, 1895*]

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, March 20, 1895.

Mr. H. R. HEYL, Vice-President, in the chair.

Present, 172 members and thirty-two visitors.

Additions to membership since last report, nine.

The Secretary read letters from Messrs. H. R. Heyl and Chas. A. Hexamer, accepting election, respectively, to the office of Vice-President, and to membership in the Committee on Science and the Arts. Also, a communication from the Wyoming Historical and Geological Society of Wilkes-Barre, Pa., announcing the death of Mr. Sheldon Reynolds, the late president of the society and life member of the Franklin Institute. It was ordered that due notice of the fact be entered upon the minutes of the meeting.

The Secretary announced that, in accordance with the action taken at the

stated meeting, held February 20, 1895, the President had appointed a special committee, of which Mr. William Sellers was named as chairman, to consider the expediency of co-operating with the *Verein Deutscher Ingenieure* in an international movement for the unification of screw-thread standards. A communication was read from the chairman making a report of progress.

Mr. Lawrence T. Paul was elected to fill the vacancy in the Board of Managers, caused by the election of Mr. Heyl to the office of Vice-President.

The paper of the evening was entitled "The Carbides and Acetylene Commercially Considered," by Mr. Thos. L. Willson and Dr. J. J. Suckert, of New York.

The paper gave an exhaustive historical account of the subject, leading up to the interesting discovery, by Mr. Willson, of a practical method of producing, on the commercial scale, in the electric furnace, the metallic carbides, and especially calcium carbide; the production therefrom of acetylene, by bringing the carbide in contact with water; and the industrial bearings of the several inventions embraced in Mr. Willson's work, principally in connection with questions of the cheap production of acetylene for illuminating purposes.

The paper was profusely and brilliantly illustrated by experiments, showing the generation of the gas by the decomposition of water, the solidification of acetylene with the cold produced by the vaporization of the liquefied gas, and the illuminating value of acetylene. Acetylene forms a snow-white solid, showing by the thermometer a temperature of — 118° F. Mercury surrounded by the solid substance was readily frozen. The brilliant whiteness of the acetylene flame burning from a series of one-foot Bray tips was capitally shown by comparison with the ordinary coal gas flame, and incandescent and arc electric lights, simultaneously in operation. The shadow of a common gas flame from a six-foot burner was distinctly shown projected on a white screen with the aid of one of the small acetylene jets above referred to.

The historical portion of the paper was further illustrated by the exhibition of a complete suite of specimens of various metallic carbides and related electric-furnace products, and of interesting derivatives, such as benzol, styrol, nitro-benzol, naphthalene, etc.

The paper evoked an extended discussion, and will appear in due course in the *Journal*.

At the close of the discussion, Mr. A. E. Outerbridge, Jr., moved a vote of thanks to the authors for their extremely interesting and valuable communication. The motion was numerously seconded and was adopted amid pronounced applause.

The Chairman, in a few appropriate remarks, expressed to Messrs. Willson and Suckert the appreciation and thanks of the Institute for their admirable presentation of the subject, and the meeting adjourned.

WM. H. WAHL, *Secretary*.

ERRATUM: Art. Outerbridge; March *Journal*, p. 226, line 8 from top; for IX *read* I. X.

PENNSYLVANIA STATE WEATHER SERVICE,

UNDER THE DIRECTION OF THE FRANKLIN INSTITUTE,

CO-OPERATING WITH THE

UNITED STATES DEPARTMENT OF AGRICULTURE, WEATHER BUREAU.

T. F. TOWNSEND, WEATHER BUREAU, OBSERVER IN CHARGE.

MONTHLY WEATHER REVIEW.

FOR FEBRUARY, 1895.

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, February 28, 1895.

GENERAL REVIEW.

The average temperature for February, 1895, 20°·2, is 9°·8 below the average [30°·0] for the past seven years.

The highest recorded temperatures occurred on the 27th and 28th, and were as follows: Pittsburgh, 60°; Altoona, 56°; Chambersburg, 56°, and Aqueduct [Logania] 56°.

The lowest were on the 6th: Emporium, minus 26°; Saegerstown, minus 25°; Smethport, minus 24°; and Shingle House, minus 23°.

With the exception of 1885, this was the coldest February in the past twenty years. Not only were unusually low temperatures recorded on the 6th, but the month was uniformly cold. The navigation of the Delaware River was practically closed for days to shipping. By the assistance of the city ice boats the ferry boats were enabled to make irregular trips. Many persons crossed the river on the ice between Philadelphia and Camden.

From January 1, 1895, to February 28, 1895, the accumulated deficiency in daily mean temperature at Philadelphia was 302°; at Erie, 328°, and at Pittsburgh, 395°.

For the same period the deficiency in precipitation, in inches, at Philadelphia, was 0·69; Erie 2·09, and at Pittsburgh, 1·01.

NOTE—Crop correspondents are requested to résume their reports the first week in April. Blanks furnished on application.

When damage occurs by lightning, observers, crop correspondents, and others, are particularly requested to furnish this office with the following statistics, as soon thereafter as practicable, viz.:

Date, place, names of persons killed or injured, whether indoors or outdoors; stock, in stable or outside; barns with crops or without crops; dwellings, churches, etc. In each case state whether the buildings were with or without lightning rods, together with any other data of interest or scientific value. Newspaper clippings containing information of this nature requested. Special cards for report furnished on application.

TEMPERATURE.

	Mean Temperature.	*Mean Precipitation, Inches.*
February, 1888, ...	28°·4	2·50
1889, ...	23°·0	1·96
1890, ...	37°·1	4·32
1891, ...	34°·9	4·61
1892, ...	31°·7	1·75
1893, ...	27°·4	5·92
1894, ...	27°·6	3·53
1895, ...	20°·2	1·22

The means of the daily maximum and minimum temperatures, 29°·6 and 10°·8, respectively, give a monthly mean of 20°·2, which is 7°·4 below the corresponding month of 1894.

The average daily range was 18°·8.

Highest monthly mean, 25°·8 at *Philadelphia* [Centennial Avenue].

Lowest monthly mean, 13°·6 at Wellsboro.

Highest temperature recorded during the month, 60° on the 28th at Pittsburgh.

Lowest temperature, minus 26° on the 6th at Emporium.

Greatest local monthly range, 75° at Emporium.

Least local monthly range, 54° at South Bethlehem and Wilkes-Barre.

Greatest daily range, 55° at Saegerstown.

PRECIPITATION.

The average precipitation for the State, for the month, 1·22 inches, is 2·29 inches less than the average [3·51] for the past seven years.

General snows occurred on the 2d, 7th, 8th, 13th and 21st. Those of the 7th and 8th were heavy, and being accompanied by high winds and low temperatures, the snow drifted badly. Railroad trains were either completely blocked or much delayed, and many country roads rendered impassable for days.

Rain occurred on the 28th, and was the only rainstorm during the month.

The largest monthly totals of snowfall in inches were: Coatesville, 28·2; Blooming Grove, 26·0; Drifton, 25·8, and Kennett Square, 21·2.

But little remained on ground at the end of the month, and this was in patches, being the remains of the heavy drifts.

The largest monthly totals of rainfall and melted snow in inches were: Blooming Grove, 3·47; Coatesville, 2·93; Stoyestown, 2·60; Drifton, 2·58; Saegerstown, 2·38, and Wilkes-Barre, 2·32.

The least were: Altoona, 0·17; State College, 0·22; Huntingdon, 0·46; Davis Island Dam, 0·46; Elwood Junction, 0·47; Emporium, 0·50; and Towanda, 0·50.

WIND AND WEATHER.

The prevailing wind was from the Northwest.

Average number: rainy days, 6; clear days, 10; fair days, 10; cloudy days, 8.

BAROMETER.

The mean pressure for the month, 30·07, is about ·03 below the normal. At the United States Weather Bureau Stations, the highest observed was 30·57 at Harrisburg on the 24th, and the lowest 29·30 at Philadelphia on the 7th.

MISCELLANEOUS PHENOMENA.

Snow.—Hamburg, 2d, 7th, 21st; Altoona, 1st, 8th, 21st, 28th; Hollidaysburg, 7th, 8th, 13th, 21st, 28th; Le Roy, 3d, 5th, 8th, 9th, 10th, 11th, 14th, 20th, 21st; Towanda, 7th, 8th, 13th; Quakertown, 2d, 4th, 8th, 13th, 21st, 23d; Cassandria, 2d, 4th, 8th, 13th, 21st, 23d; Emporium, 7th, 8th, 21st; East Mauch Chunk, 2d, 7th, 8th, 13th, 21st; State College, 2d, 7th; West Chester, 2d, 7th, 8th, 13th, 21st; Coatesville, 2d, 7th, 8th, 13th, 21st, 23d; Kennett Square, 2d, 4th, 7th, 8th, 13th, 21st; Phœnixville, 2d, 7th, 8th; Westtown, 2d, 7th, 8th, 21st; Grampian, 4th, 7th, 8th, 13th, 14th, 18th, 20th, 23d; Lock Haven, 7th, 8th, 13th, 21st; Saegerstown, 7th, 8th, 13th, 19th, 20th, 21st; Carlisle, 3d, 8th, 9th; Uniontown, 7th, 8th, 9th, 12th, 13th; Chambersburg, 7th, 8th, 13th; Huntingdon, 2d, 6th, 13th; Lancaster, 2d, 7th, 8th, 13th; Lebanon, 2d, 4th, 7th, 8th, 13th, 21st, 23d; Coopersburg, 2d, 7th, 8th, 13th, 21st, 23d; Drifton, 2d, 3d, 7th, 8th, 13th, 14th, 21st, 25th; Wilkes-Barre, 2d, 4th, 7th, 8th, 9th, 21st; Williamsport, 7th, 8th, 13th, 23d; Smethport, 8th, 9th, 21st; Greenville, 9th, 18th, 19th; Pottstown, 2d, 7th, 13th, 21st; South Bethlehem, 2d, 4th, 7th, 8th, 13th, 21st; Easton, 2d, 4th, 7th, 8th, 13th, 21st; Aqueduct, 2d, 7th, 13th, 21st; *Philadelphia* [Centennial Avenue], 2d, 4th, 7th, 8th, 13th, 21st, 23d; Blooming Grove, 2d, 7th, 8th, 9th, 13th, 21st; Shingle House, 8th, 9th, 24th; Selins Grove, 2d, 7th, 8th, 13th, 23d; Somerset, 6th, 7th, 8th, 9th, 13th, 21st; Wellsboro, 7th, 8th, 18th, 21st; Lewisburg, 7th, 8th, 21st, 23d; Dyberry, 2d, 4th, 7th, 8th, 21st; Honesdale, 2d, 4th, 7th, 8th, 13th, 21st; Salem Corners, 2d, 4th, 5th, 8th, 13th, 21st, 22d; South Eaton, 7th, 8th; York, 2d, 7th, 8th, 13th, 21st.

Aurora.—Le Roy, 14th, 15th, 23d; Saegerstown, 15th, 23d; Dyberry, 15th, 23d.

Solar Halo.—Le Roy, 12th, 27th; Towanda, 12th, 20th; South Bethlehem, 7th; *Philadelphia* [Weather Bureau], 1st, 3d, 6th, 12th; [Centennial Avenue], 1st, 6th, 12th, 19th, 27th; Wellsboro, 12th.

Lunar Halo.—Le Roy, 3d, 6th; Towanda, 3d, 6th; Emporium, 7th; West Chester, 1st, 6th; Phœnixville, 6th; Lebanon, 1st, 6th; *Philadelphia* [Weather Bureau], 1st, 3d, 6th, 12th; [Centennial Avenue], 1st, 3d, 6th; Wellsboro, 3d; Lewisburg, 6th.

PRECIPITATION DURING FEBRUARY, 1895.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	Total.
Delaware Basin																																
Bethlehem,		.14					.65														.05							.05				0.89
Blooming Grove,		.10					‡	‡	2.00				.20	.81							.36											3.47
Browers Lock,		.26					.19	.39					.14								.02							.08				1.08
Coatesville,		.40					1.00	1.00					.20								.20		.02					.11				2.93
Coopersburg,		.16					.27	1.00					.10								.09		.01					.08				1.71
Doylestown,		.59		.09			.29	.14													.08		.04					.06				1.29
Dyberry,		.04		.04			.21	.40													.05											0.74
Easton,		.30		.10			‡	1.10					.03								.01							.01				1.55
Forks of Neshaminy,		.28		.01			.28						.05								.03							.09				0.74
Frederick,		.19		.02			.20	.21					.03								.05							.16				0.88
Hamburg,		.09					.46														.16											0.71
Honesdale,		.06		.06			.40	.31					.03								.07											0.93
Kennett Square,		.30		.02			.40	.58					.15								.07							.16				1.68
Lansdale,		.58		.10			.17	.26													.10							.13				1.34
Mauch Chunk,		.13					.27	1.33					.07								.13							.09				2.02
Ottsville,		.20					.00	.52					.04								.03											0.88
Philadelphia, a†		.27					.30	.43					.10								.03							.26				1.39
Philadelphia, b,		.18					.34	.40					.09								.03							.24				1.28
Phœnixville,		.31		.03			.47	.45					.17								.04						.09	.02				1.58
Point Pleasant,		.23					.26	.18					.02															.04				0.73
Pottstown,		.25					1.00						.06								.05							.18				1.48
Quakertown,		.16		.05			‡	1.09					.03								.10		.02					.09				1.47
Reading,		.12		.01			.30	.18					.15								.06		.01					.03				1.16
(Salem Corners) Hamlinton,		.10		.08	.03		‡	.80					.05								‡	.48						.04				1.58
Seisholtzville,		.17					.90	.83					.11								.07							.10				2.18
Smith's Corner,		.25					.17	.20													.07							.08				0.77
Swarthmore,																																
West Chester,		.21					‡	1.00					.17								.05							.18				1.61
Westtown,		.20					‡	.40					.20								.07							.15				1.02
Susquehanna Basin.																																
Altoona,	.02							.08													.02							.05				0.17
(Aqueduct) Logania,		.09					.48						.09								.04						.01	.03				0.74
Carlisle,		*	.13					1.05	.10	.10																		.01				1.39
Drifton,		.10	.13				.35	1.40		*			.40	.05				*			.10	*		*	.05							2.58
Emporium,							.15	.15													.20											0.50
Girardville,		.12					.50	.40					.16	.08							.16	.12										1.54
Grampian,				.06			‡	.25					.14	.10					.09		.12		.06					.14				0.96
Harrisburg,†		.07					.11	.24					.02															.10				0.54
Hollidaysburg,							.34	.23					.21								.09							.16				1.03
Huntingdon,		.05				.30							.02															.09				0.46
Lancaster,		.17					‡	1.00					.19														‡	38				1.74
Lebanon,		.12		.01			.40	.09					.08								.03		.01					.13				0.87
Le Roy,			.03		.01			.20	.25	.05	.03			.10						.10	.03											0.80
Lewisburg,							.70	.40													.10		.10					.05				1.35
Lock Haven,							.40	.40					.10								.10											1.00
Selins Grove,		.20					.65	.25					.05								.06		.05									1.26
South Eaton,		.10					‡	1.00													.10	.05						.08				1.33
State College,		.03					.19																									0.22
Towanda,							‡	.40					.10																			0.50
Wellsboro,							‡	.65										.15			.05											0.85
Wilkes-Barre		.20		.15			.30	1.10	.36												.21											2.32
Williamsport,	*	*	*	*	*	*	.50	.04					.02										.03									0.59
York,		.15					.35	.16					.15								.02	.01						.14				0.98

	1	2	3	4
Ohio Basin.				
Beaver Dam,		.02		.02
Brookville,				
Cassandria,		.05		.10
Clarion,		.04	.02	.01
Confluence,		.10		.02
Davis Island Dam,				
DuBois,				
Elwood Junction,				
Freeport,		.04		
Greensboro,		.07		.02
Greenville,				
(Immel Reservoir) Lycippus,		.05		
Johnstown,		.03		.01
Lock No. 4,		.02		
Mahoning,		.02		.01
Oil City,				.05
Parker's Landing,		.01		.02
Pittsburg,†		.01		.01
Ridgway,		.02		
Saegerstown,				
Saltsburg,		.02		.02
Shingle House,				
Smethport,				
Somerset,				
Stoyestown,			.12	.15
Uniontown,			.12	.40
Warren,				.01
West Newton,		.02		
Potomac Basin.				
Chambersburg,		.01		
Lake Basin.				
Erie,†	.03	.01		.13

†U. S. Weather Bureau Stations. *Missing. ‡Amount included in measurement following.

PRECIPITATION DURING FEBRUARY, 1895.

	1	2	3	4	5	6	7	8	9	10	11	12	13	21	22	23	24	25	26	27	28	29	30	31	Total.
Ohio Basin.																									
Beaver Dam,	..	.02	..	.02	..	..	.08	.11	.03	..	..	..	.12	.05	..	..	..	..	..	..	.05	..	..	..	0.89
Brookville,	..	..	..	..	.02	..	..	.13	.22	..	..	..	..	.36	..	..	..	..	..	..	..	..	..	..	3.47
Cassandria,	..	.05	..	.10	..	..	.30	..	..	..	..	.10	..	.02	..	..	..	..	..	..	.08	..	..	..	1.08
Clarion,	..	.04	.02	.01	.01	..	.03	.16	.12	.07	..	..	.08	.20	..	.02	..	..	..	..	.11	..	..	..	2.93
Confluence,	..	.10	..	.02	.10	..	.20	.30	.09	..	..	..	.18	.09	..	.01	..	..	..	..	.08	..	..	..	1.71
Davis Island Dam,	..	..	..	..	..	..	.06	.03	.01	..	..	..	.02	.08	..	.04	..	..	..	..	.06	..	..	..	1.29
DuBois,	..	..	..	..	..	..	.07	.27	.17	..	..	..	.19	.05	..	..	..	..	..	..	..	..	..	..	0.74
Elwood Junction,	..	..	..	..	..	..	..	..	.01	..	..	..	..	.01	..	..	..	..	..	..	.01	..	..	..	1.55
Freeport,	..	.04	..	..	..	..	.07	.22	.15	.05	..	..	.09	.03	..	..	..	..	..	..	.09	..	..	..	0.74
Greensboro,	..	.07	..	.02	.01	..	.20	.20	.04	..	..	..	.14	.05	..	..	..	..	..	..	.16	..	..	..	0.68
Greenville,	..	..	..	..	..	..	..	..	.50	..	..	..	..	.16	..	..	..	..	..	..	..	..	..	..	0.71
(Immel Reservoir)																									0.93
Lycippus,	..	.05	..	..	..	..	.17	..	..	.21	..	..	.26	.07	..	..	..	..	..	..	.16	..	..	..	1.66
Johnstown,	..	.05	..	.01	.01	..	.06	.18	.01	..	..	..	.04	.10	..	..	..	..	..	..	.13	..	..	..	1.34
Lock No. 4,	..	.02	..	..	..	..	.10	.20	.05	..	..	..	.05	.13	..	..	..	..	..	..	.09	..	..	..	2.02
Mahoning,	..	.02	..	.01	..	..	..	.10	.06	.02	..	..	.05	.03	..	..	..	..	..	..	..	..	..	..	0.88
Oil City,	..	..	..	.05	.03	..	.01	.15	.14	.05	..	.03	.04	.03	..	..	..	..	..	..	.26	..	..	..	1.39
Parker's Landing,	..	.01	..	.02	.02	..	.01	.02	.12	.05	..	..	.01	.03	..	..	..	..	..	..	.24	..	..	..	1.28
Pittsburg,†	..	.01	..	.01	..	.05	.19	.08	..	..	..	.06	.04	.04	..	..	..	..	..	.09	.02	..	..	..	1.58
Ridgway,	..	.02	..	..	..	..	..	.15	..	.30	..	..	..	..	..	..	..	..	..	..	.04	..	..	..	0.73
Saegerstown,	..	..	..	..	..	..	..	.60	.55	..	..	..	.05	.05	..	..	..	..	..	..	.12	..	..	..	1.48
Saltsburg,	..	.02	..	.02	.03	..	.11	.32	.02	.05	..	..	.12	.09	..	.02	..	..	..	..	.09	..	..	..	1.47
Shingle House,	..	..	..	..	..	..	..	.20	.40	..	..	..	..	.06	..	.01	..	..	..	..	.03	..	..	..	1.16
Smethport,	..	..	..	..	..	..	..	‡	.40	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Somerset,	..	..	..	..	..	..	.10	.42	.10	.11	..	..	.34	.04	..	.48	†	..	..	..	.04	..	..	..	1.58
Stoyestown,	..	..	.12	.15	.20	.30	.20	.40	..	.10	..	.10	.20	.10	..	..	..	..	..	..	.10	..	..	..	2.18
Uniontown,	..	..	.18	.40	.15	.12	..	..	.15	.10	..	..	..	.07	..	..	..	..	..	..	.08	..	..	..	0.77
Warren,	..	..	..	.01	.01	..	..	.09	.20	..	..	..	.10	..	..	..	..	..	..	..	..	..	..	..	..
West Newton,	..	.02	..	..	..	..	.09	.21	..	..	..	..	.08	.05	..	..	..	..	..	..	.18	..	..	..	1.61
Potomac Basin.														.07	..	..	..	..	..	..	.15	..	..	..	1.02
Chambersburg,	..	.01	..	..	..	..	.20	.80	..	..	..	..	.05	..	..	..	..	..	..	..	..	..	..	..	0.17
Lake Basin.														..	..	..	..	..	..	..	..	..	..	..	..
Erie,†	.03	.01	..	.13	..	..	.14	.21	.09	..	..	..	.06	.04	..	..	..	..	..	.01	.03	..	..	..	0.74
														..	..	..	..	..	..	..	.01	..	..	..	1.39
														.10	•	..	..	•	.05	..	..	..	..	..	2.58
														.20	..	..	..	..	..	..	..	..	..	..	0.50
														.16	.12	..	..	..	..	..	..	..	..	..	1.54
														..	..	.06	..	..	..	..	.14	..	..	..	0.96
														..	..	..	..	..	..	..	.10	..	..	..	0.54
														.09	..	..	..	..	..	..	.16	..	..	..	1.03
														..	..	..	..	..	..	..	.09	..	..	..	0.46
														..	..	..	..	..	..	‡	38	..	..	..	1.74
														.03	..	.01	..	..	..	..	.13	..	..	..	0.87
														.03	..	..	..	..	..	..	..	..	..	..	0.80
														.10	..	.10	..	..	..	..	.05	..	..	..	1.35
														.10	..	..	..	..	..	..	..	..	..	..	1.00
														.06	..	.05	..	..	..	..	..	..	..	..	1.26
														.10	.05	..	..	..	..	..	.08	..	..	..	1.33
														..	..	..	..	..	..	..	..	..	..	..	0.22
														..	..	..	..	..	..	..	..	..	..	..	0.50
														.05	..	..	..	..	..	..	..	..	..	..	0.85
														.21	..	..	..	..	..	..	..	..	..	..	2.32
														..	..	.03	..	..	..	..	..	..	..	..	0.59
														.02	.01	..	..	..	..	..	.14	..	..	..	0.98

10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	Total.
. .	. .	. .	·12	. .	. .	. .	. .	. .	. .	. .	·02	·01	·01	. .	. .	. .	. .	·31	. .	. .	. .	0·73
. .	. .	. .	. .	·06	·02	. .	. .	. .	·11	. .	·18	·07	·05	·02	. .	. .	. .	·11	. .	. .	. .	0·99
. .	. .	·10	. .	. .	. .	. .	. .	. .	. .	. .	·30	. .	·20	. .	. .	. .	. .	·40	. .	. .	. .	1·45
·07	. .	. .	·08	·07	·12	. .	. .	. .	·18	. .	·19	·34	·08	·01	. .	. .	. .	·65	. .	. .	. .	2·18
. .	. .	. .	·18	·01	·02	. .	. .	. .	. .	. .	. .	·09	. .	·02	. .	. .	. .	·30	. .	. .	. .	1·43
. .	. .	. .	·02	. .	. .	. .	. .	. .	. .	. .	. .	·02	. .	. .	. .	. .	. .	·32	. .	. .	. .	0·46
. .	. .	. .	·19	. .	·05	. .	. .	. .	·16	. .	·21	·10	·06	. .	. .	. .	. .	·30	. .	. .	. .	1·58
. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	·11	. .	. .	. .	. .	. .	·35	. .	. .	. .	0·47
·05	. .	. .	·09	. .	·04	. .	. .	. .	. .	·02	·06	. .	. .	. .	. .	. .	. .	·50	. .	. .	. .	1·24
. .	. .	. .	·14	·02	·03	. .	. .	. .	. .	. .	·06	·03	. .	·02	. .	. .	. .	·24	. .	. .	. .	1·08
. .	. .	. .	. .	. .	. .	. .	. .	·10	·03	. .	. .	. .	. .	. .	. .	. .	. .	·45	. .	. .	. .	1·08
·21	. .	. .	·26	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	·10	. .	. .	. .	0·79
. .	. .	. .	·04	·10	·01	. .	. .	. .	. .	. .	·02	·13	. .	. .	. .	. .	. .	·40	. .	. .	. .	0·98
. .	. .	. .	·05	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	·16	. .	. .	. .	0·58
·02	. .	. .	·05	. .	. .	. .	. .	. .	. .	. .	·03	. .	. .	. .	. .	. .	. .	·30	. .	. .	. .	0·59
·05	. .	·03	·04	·03	·03	. .	. .	·07	·05	·02	·15	·08	·04	. .	. .	. .	. .	·52	. .	. .	. .	1·49
·05	. .	. .	·01	. .	·01	. .	. .	. .	·15	. .	·10	·06	·02	. .	. .	. .	. .	·24	. .	. .	. .	0·84
. .	. .	·06	·04	. .	. .	. .	. .	. .	. .	. .	·03	. .	. .	. .	. .	. .	·02	·28	. .	. .	. .	0·77
·30	. .	. .	. .	·10	. .	. .	. .	. .	·03	. .	·20	·04	·01	. .	. .	. .	. .	·21	. .	. .	. .	1·06
. .	. .	. .	·05	. .	. .	. .	. .	. .	·08	·30	·35	. .	. .	. .	. .	. .	. .	·45	. .	. .	. .	2·38
·05	. .	. .	·12	·03	·01	. .	. .	. .	. .	. .	·03	·08	·01	. .	. .	. .	. .	·50	. .	. .	. .	1·35
. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	·40	. .	. .	. .	. .	. .	. .	. .	1·00
. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	·50	. .	. .	. .	. .	. .	. .	·20	. .	. .	. .	1·10
. .	. .	. .	·34	. .	. .	. .	. .	. .	. .	. .	·21	. .	. .	. .	. .	. .	. .	·28	. .	. .	. .	1·56
·10	. .	·10	·20	·20	. .	. .	. .	. .	. .	. .	·05	·23	·06	. .	. .	. .	. .	·29	. .	. .	. .	2·60
·10	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	·35	. .	. .	. .	1·39
. .	. .	. .	·10	·10	. .	. .	. .	. .	·09	·01	·19	·01	·10	. .	. .	. .	. .	·03	. .	. .	. .	0·94
. .	. .	. .	·08	. .	. .	. .	. .	. .	. .	. .	. .	·05	. .	. .	. .	. .	. .	·35	. .	. .	. .	0·80
. .	. .	. .	·05	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	·01	. .	. .	. .	1·57
. .	. .	. .	·06	. .	. .	. .	. .	·06	. .	. .	·18	. .	·15	. .	. .	. .	·14	·13	. .	. .	. .	1·33